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THE PHYSIOGRAPHY OF THE ADIRONDACKS

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Introduction.—The state of New York is shaped like a shoe, with its toe pointing due west and a long spur extending from the heel to the east. In the upper part of the shoe where the ankle of the wearer would be placed, is the Adirondack region, containing 10,000 square miles of very sparsely inhabited mountain, plateau and forest. It embraces the highest summits in the state, and at the same time the highest in eastern North America, except the White Mountains of New Hampshire and the Blue Ridge of North Carolina. Were it not for these two, even though the Appalachian region is decidedly and impressively mountainous, the Adirondacks would remain the loftiest summits in the east; and the equal of Mt. Marcy, called Tahawus or the 'Cloud-splitter' by the Indians, would not appear on the hither side of the Black Hills of South Dakota or the remoter Rocky Mountains.

Geological Formations Present.—The Adirondack region in its geology presents an important and interesting series of Precambrian rocks. Roughly speaking, nearly the whole area consists of gneisses, but the metamorphic rocks can be separated into a great series of sedimentary gneisses, quartzites and coarsely crystalline limestones, on the one hand, and, on the other, into a second great series of eruptive syenites, granites and rocks of the gabbro family. Except for the limestones, all these rocks are hard and resistant, their weak points of attack being in a small degree their schistosity, and in a greater degree their joints and faults.

On all sides the Precambrian rocks are mantled with the Paleozoics, the oldest of which is the Potsdam sandstone of the Upper Cambrian, a hard quartzite, gray, pink and pale yellow in color. The latest member of the Paleozoics having any association with the old crystallines

is the Utica slate, near the top of the Ordovician, while between the Potsdam and the Utica appear in order from below, upward, the Beekmantown, Chazy and Trenton limestones. Except perhaps the Utica slate and the Trenton limestone, which is somewhat shaly, all these are firm, resistant rocks. The visible contacts of the Paleozoic strata with the old crystallines, especially on the northwest and west, are often those of sedimentary overlap, due to an advancing shore line, but on the east and northeast they are much more frequently due to block-faulting of a most interesting character and exceedingly significant as throwing light on the physiography of the interior mountains. Aside from this, however, the Paleozoic strata enter only in a very minor way

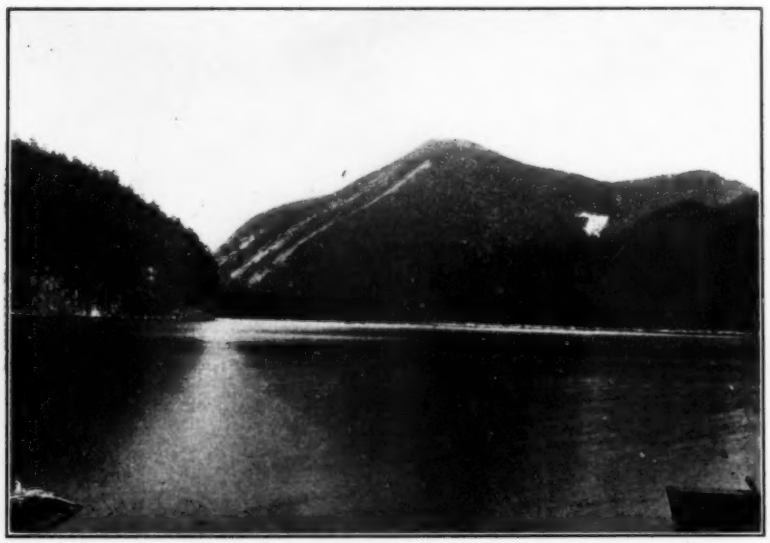

FIG. 2. MT. MCINTYRE, THE SECOND PEAK IN ALTITUDE—viewed from the southeast. The side towards the observer is very steep.

into the structure of the mountains. They occur around the edges, except for a few isolated outliers from five to forty miles within the Precambrian area.

After the deposition of the Utica, so far as the actual evidence is concerned, there were no more rocks laid down until the advent of the Labradorean ice sheet of the Glacial epoch. Whether later Paleozoics once existed and have been removed by erosion, or whether the area has been continuously land from the close of the Ordovician to the present, may be esteemed to a certain extent open to debate. From observations near Little Falls on the southern side, Professor H. P. Cushing has concluded that the Niagara limestone probably extended a long distance into the area of the crystallines if not entirely across. But no trace of it has been discovered in place, and the great gap in time from

the Ordovician to the Glacial epoch must be interpreted, if at all, by the structural and physiographic records. The Labradorean ice sheet was, however, of enormous importance. Its deposits are heavy, and it doubtless operated to form numberless lakes and to greatly reorganize the drainage, as will be later pointed out in a few suggestive instances.

The Mountains Proper and the Western Plateau.—The Adirondack region, sometimes referred to as the Great North Woods, is mountainous in its eastern half, and has its highest peaks near its center, but on the west the mountains disappear and the area becomes a plateau ranging from 2,000 feet above tide gradually downward to the west until it is but slightly higher than Lake Ontario and the St. Lawrence. The

FIG. 3. MT. WHITEFACE FROM FRENCH'S HOTEL ON THE NORTH. Steep and narrow passes bound it on either side.

loftiest peak is Marcy, 5,344 feet, and there are one or two others which exceed 5,000, together with five or six additional above 4,500, and many above 3,000. The mountains are ranged in visible northeast and southwest lines, and are often very steep if not positively precipitous in the portions that look to the southeast or northwest. There are also other steep faces nearly at right angles with the above, but they are less pronounced. When viewed from a distance the profile is strongly serrate —a gradual slope up on one side being cut off abruptly by an almost vertical descent on the other.

The individual mountains are diversified in shape. Mt. Marcy is a very low cone, and the last stages of its ascent are very much like climbing a dome. Mt. McIntyre has a gradual slope from the northwest,

FIG. 4. MT. HURRICANE FROM THE WEST, a relatively flat summit.

FIG. 5. THE SUMMIT OF MT. WHITEFACE ILLUSTRATING THE WASTING-AWAY ALONG JOINTS.

but a precipitous escarpment on the southeast. The Gothics are like a steep wedge standing on its base, and tapering from all four sides of the base to the ridge. Whiteface is a long sharp ridge, steep if not actually precipitous on each side, and leading up to a peak at the southwestern end. Some buttresses run out from the ridge and make beautiful cirques on its flanks. Hurricane, when viewed from the east, resembles a sharp volcanic cone; from the west it is flat. There are several, of which Dix is the highest example, which, like Vesuvius, have a small conical summit set upon a large mountainous base. Nippletop is a rather favorite name in the local nomenclature of the inhabitants. There are several smaller mountains which have the outlines of a steep haystack when viewed from certain directions, and their precipitous sides and doming tops fix the eye at once. Yet they may each be a ridge when seen from the opposite. One very exceptional peak, quite inappropriately called Sugarloaf, near Hulett's on Lake George, is a circular mesa, with a flat top several acres in area and dropping with steep sides to the lake slope below. It resembles a round fort or old-time castle, such as St. Angelo, across the Tiber from Rome, or Castle William on Governor's Island in New York Harbor. It is due to flat foliation in the gneisses combined with intersecting vertical joints. Not a few other mountains, although of very irregular shapes at the base, yet have flat tops of considerable area. Their level summits appear to be the surviving remnants of some old-time peneplain now faulted into relief, as will be later explained.

The plateau portion, which makes up practically the western half, is not absolutely flat, but is more or less diversified with low hills and intervening broad valleys. Occasional summits give views of moderate extent, but no elevations can properly be called mountains, and the general term plateau is most expressive. It may well be the remnant of an old peneplain, perhaps the important one widely developed in Cretaceous time in the east.

The Valleys.—The mountains can not all be described without parallel and complementary reference to the valleys, and in discussing the latter the causes which have led to the production of the former may best be mentioned.

At least two marked and contrasted types of valleys may be distinguished. There is an old series which in part probably dates back even to Precambrian time. In the eastern mountains the cause of their excavation is oftentimes obviously the presence of relatively soft and easily eroded limestone in the series of gneisses. In several notable cases the Potsdam and even later Paleozoic formations can be traced by the remaining outliers some miles into the old crystallines, and although subsequent faulting has exercised its modifying and disguising influence, yet it has appeared to several observers that the old

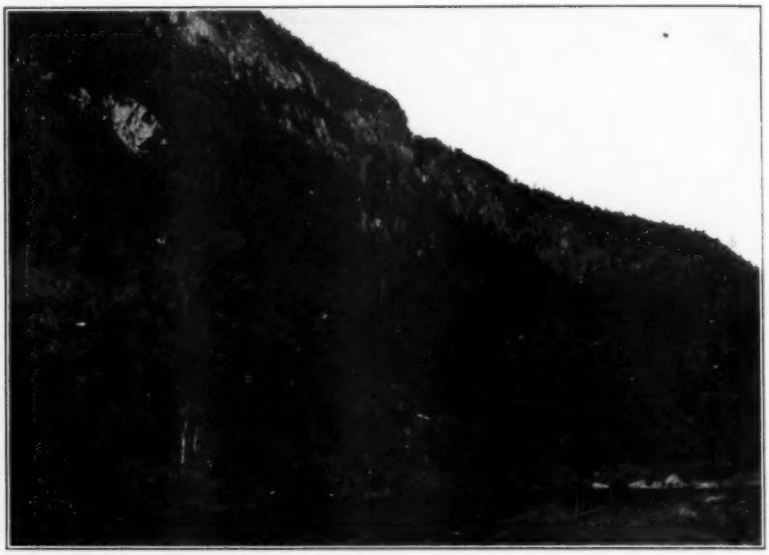

FIG. 6. PRECIPITOUS CLIFFS ALONG THE NORTHWESTERN SIDE OF THE WILMINGTON NOTCH—illustrating the northeast and southwest type of fault valley.

depressions were recognizable. The old valleys have gentle slopes and wide expanses. Their contours are softened down and the whole physiographic expression is one which suggests long-continued erosion and maturity of form. In studying out these relations, one has also to eliminate as far as possible the mask of glacial drift which is everywhere in evidence. The valleys of the old system run in their most marked development east and west, and north and south. Several of them are occupied to-day by some of the largest streams and lakes—such as Schroon lake, the southern third of Lake George, parts of the Hudson Valley and several tributary to Lake Champlain. One half of an old valley will often remain with characteristically gentle slope and mild topography, while the other half of the depression will consist of the steep precipices of the next type. And as the second type has been superimposed upon the first, the observer is often forced to trace the former out despite its disguises and modifications.

The second type of valley is obviously the result of faulting, and of faulting that is of no great geological antiquity. The sides and steep escarpments and the depressions may have all the characteristics of a 'Graben-senkung,' or of a fjord, if the latter can be imagined away from the sea. In the southeastern portion of the mountains as well as in the interior, three pronounced sets of fault escarpments may be recognized and plotted. The most marked one is northeast, and to it is due the general northeast and southwest trend of the mountains. The topographic maps, and still more the relief model prepared by

E. A. Howell, show this in all desirable clearness. Along the shores of Lake Champlain the ridges come in one after another from the southwest, making the western shore of the lake a series of bays with bold intervening headlands. The central portion of Lake George, where the wildest and most picturesque scenery is found, is another example. Precipitous escarpments characterize the shores, while mountains of rugged outline shut in the observer. In the interior these characters appear on an even grander scale. The Lower Ausable lake is a Graben; Avalanche lake, one of the sources of the Hudson, has cliffs so steep that the traveler must take to a boat to find a passage. In Wilmington notch, as also in Indian pass, cliffs hardly less than a thousand feet, front the traveler.

A second but less strongly developed series of faults runs northwest and southeast and is the cause of many cross breaks at right angles with the set last mentioned. They serve to block out the individual mountains amid the general northeast trend of the ridges, and are responsible for innumerable little cross-passes which are found on all the summits. In the high mountains, the little cross-passes almost always have a well-defined bear or deer trail following them through. They serve also to develop sharp shoulders in the precipices of the first type and to give the shores of a lake a very serrated outline. In the Mount Marcy and Elizabethtown quadrangle they, with the first set, have occasioned the interesting 'lattice-shaped' drainage noted by Professor Brigham some years ago. The little streams flow

FIG. 7. THE CASCADE LAKES, BETWEEN THE KEENE VALLEY AND LAKE PLACID—illustrating the northwest and southeast faulted valley.

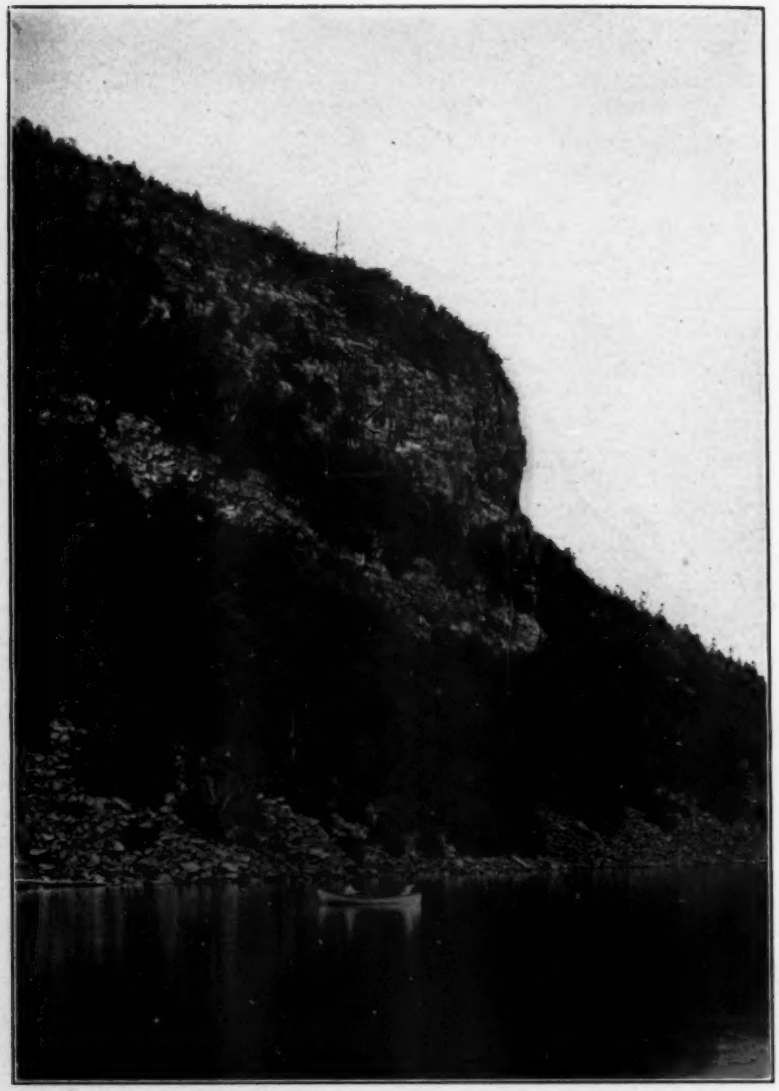

FIG. 8. DEER'S LEAP, AN ESCARPMENT ON LAKE GEORGE—produced by intersecting northeast and northwest joints, or perhaps faults—and much freshened by the ice of the Glacial epoch.

down moderate slopes from the northwest, against high and sparsely wooded precipices on the southeast and join larger streams which flow northeast or southwest. When a wide area is studied, it is only the older and still surviving east and west or north and south valleys which break up this lattice-like regularity.

In less frequent occurrence than the northeast and northwest fault breaks, minor ones ranging nearly due north may be recognized—but they do not exercise so important an influence on the general relief.

The three systems of faults have in some instances led to great single precipitous escarpments suggesting that the movement was chiefly confined to one single plane, but it is much more common to find the fault a compound one. That is, a very steep mountain face will consist of a series of small escarpments, each with a bench at its foot. These benches make terraces, and on Lake George one can easily see, even when the mountain is thickly forested, that the trees are growing in pronounced rows with thinner lines of vegetation between. A mountainside may thus look like a gigantic series of furrows, as is true of the ridge from Black Mountain to Elephant Mountain. Where the faults cut across a projecting shoulder the terraces go up one side and down the other like a series of lunettes. Forest fires and the lumberman's axe, while destroying much of the beauty, have yet brought out these features with striking emphasis, and when the light intensifies the relief with shadows they appeal to the observer in the strongest way. The narrow ridge between Lake George and Lake Champlain contains some of the roughest country in all the Adirondack region.

The faults and their escarpments were doubtless much freshened up by the Labradorean ice-sheet which plucked away from their faces the loose rock, sheeted by the parallel faults. In this way the relief was heightened during the Glacial epoch, and its freshness and youth still remain to us, but the faults preceded the ice and were the great governing factors. Thus far no evidence of post-glacial faulting has been observed.

On the south side of the mountains the faults run out in a striking way into the overlapping Paleozoic areas and have been traced as much as thirty or forty miles. One famous one causes the Precambrian rocks on the west to abut sharply for thirty miles against the Cambrian and Ordovician strata, forming an escarpment which faces east. After the Precambrians have disappeared below the Paleozoics for two miles, they rise again into view at the pass called the 'Needles,' where the Mohawk river, the Erie Canal and the New York Central and West Shore Railways find a way close together fifty miles west of Albany. Another is responsible for the Precambrian outlier of Little Falls, recently described by Professor H. P. Cushing. The displacements ex-

hibited in these easily recognized and contrasted strata are of great significance when taken as illuminating the more obscure relations of the Precambrians of the interior mountains.

One interesting corollary of the great northeast and southwest breaks is that a series of basaltic dikes which are widely distributed, which followed the metamorphism of the Precambrian rocks, but which preceded the Potsdam, almost always come up through them and suggest that the breaks go far enough down to have tapped off a reservoir of basic rocks.

The Drainage.—The waters from the Adirondacks flow into both the Hudson and the St. Lawrence Rivers. On the south and southwest they either go directly to the former which rises in their very center;

FIG. 9. SPRUCE MOUNTAIN, NEAR HULETTS, LAKE GEORGE—and viewed from the northwest. A fault—escarpment faces the observer.

or else they pass first through the Mohawk. On the north and east, the waters reach the St. Lawrence *viâ* Lakes George and Champlain, and on the northwest *viâ* Lake Ontario or directly to the great river itself. The drainage of the high mountains, however, goes almost entirely to the Hudson or to Lake Champlain.

The chief rivers actually in the area are the Hudson and its principal tributary north of Waterford, the Sacondaga, both of which will be shortly described in greater detail; West Canada Creek, and minor tributaries of the Mohawk; the Black, flowing into Lake Ontario; the Oswegatchie, Grass, Raquette, and Salmon-Chateaugay, which pass directly into the St. Lawrence; and the Saranac, Ausable and the outlet of

Lake George directly into Lake Champlain. Some of these are largely, if not essentially, preglacial in their courses, occupying the earlier valleys mentioned above. Others have been obviously influenced in their present locations by the glacial deposits. It is clear from the insuperable rocky obstacles presented that drainage must even in the preglacial period have radiated from the central height of land, and that there is a marked preglacial divide around Mt. Marcy which at this time separated the waters going north from those going south. But there are some strange features about the present courses of the Hudson and Sacondaga and some interesting points about Lake George which will be briefly noted.

FIG. 10. A FAULT IN PALEOZOIC STRATA NEAR ESSEX, N. Y., ON LAKE CHAMPLAIN. The Utica slates, from flatness on the left beyond the picture, are dragged to a fairly steep inclination, where faulted against the hard Beekmantown limestone, which lies several hundred feet below in the stratigraphic series.

The Hudson gathers its waters first from a series of beautiful mountain lakes almost under Mts. Marcy and McIntyre, the loftiest two peaks, and flows nearly due north for fifteen miles, following, no doubt, one of the older north and south valleys. It then turns abruptly westward, winding for five miles amid hillocks of drift, and tapping a notable series of east and west lakes near Newcomb village, doubtless impounded in one of the old east and west valleys. It then turns nearly due south for ten miles and makes an abrupt bend, of somewhat less than ninety degrees, to the eastward, being apparently diverted into an east and west valley by a barrier of drift. Just after it makes the turn it receives the waters of Indian River coming from a drift-

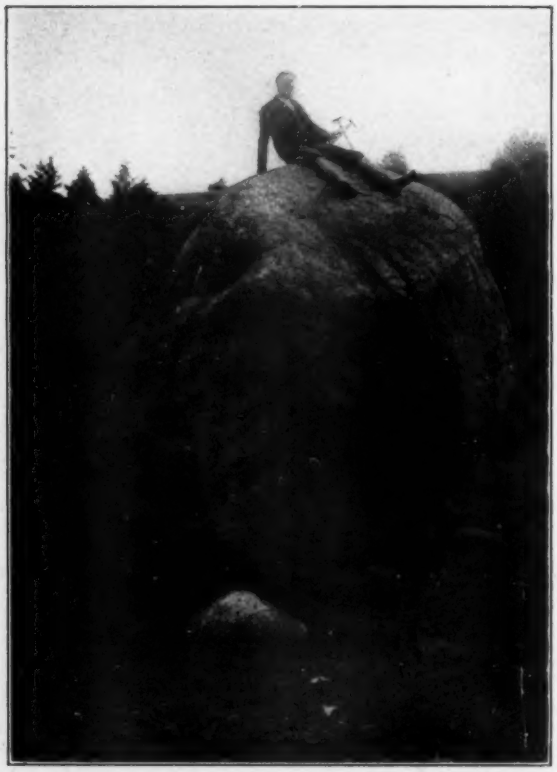

FIG. 11. A GLACIAL BOULDER IN THE KEENE VALLEY.

covered, open and swampy area to the southwest and directly in the line of its previous courses. It is apparently a case of reversed drainage. After a somewhat sinuous easterly course of eight or ten miles, the Hudson turns again abruptly south, receiving at the same time the Boreas River, which comes in from the north with the waters of a broad, open region much masked by drift and filled with swamps and lakes. It would seem as if the Hudson had jumped thus from one older drainage line to another. The Hudson next flows due south for four or five miles, then turns once more eastward, for eight miles, then south and southeast until it again turns eastward, northward and finally eastward with marked meanders across the great sandy plain near Glens Falls. Finally at Sandy Hill it swings around once more to the south and takes its nearly uniform course for the sea.

The Sacondaga River has also this same peculiar rectangular bending from north and south to east and west courses, and with a most peculiar turn parallel in all respects to the bend of the Hudson, it swings into the latter some miles above Glens Falls.

These bendings are in large part to be explained by the old series

of east and west and north and south valleys and by the rearrangements of the older drainage by the glacial drift. When the streams sought to occupy their old north and south channels on the retreat of the ice they seem to have been forced in instances by newly acquired barriers to run in an easterly direction across old but low divides and then to utilize parallel north and south lines of drainage.

Lakes.—The Adirondack region, like all the recently glaciated country, teems with lakes which can be observed in all stages from those of large size like Champlain, George and Schroon, through smaller ones, to those little more than a morass, and finally to cultivated meadow land upon the abandoned bottoms of departed ones whose deltas and terraces stand out clearly. Lake Champlain is the largest and has a total length of 150 miles. It has been recently studied in detail by Professor J. B. Woodworth. It is obviously an old river valley, probably modified somewhat by recent faulting and ponded by some barrier of recent formation at the north. Lake George is next in size and is apparently compounded of two earlier valleys, whose divide

FIG. 12. AUSABLE CHASM, whose zig-zags are due to faults and joints. The walls are hard Potsdam quartzite.

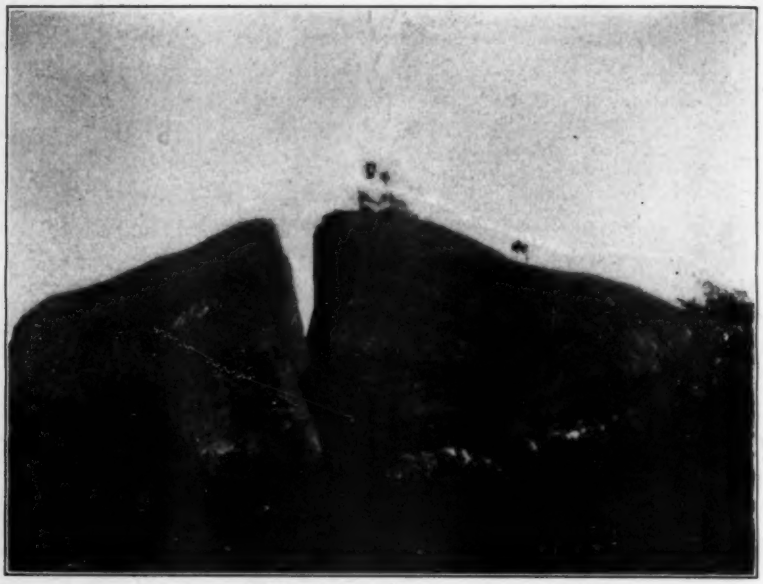

FIG. 13. CLEFT GLACIAL BOULDER NEAR HAGUE ON LAKE GEORGE.

FIG. 14. AN OLD DELTA NEAR ELIZABETHTOWN FRESHLY EXPOSED BY A HEAVY FRESHET.

was near the Hundred Islands about midway of its length. One old valley headed up in Northwest Bay, and the other probably did not come much south of Sabbath Day Point. Faulting connected them, however, and the damming by the drift of the old outlet to the south at the head of Kattskill Bay and of the normal outlet to the north into the Trout Brook Valley or possibly eastward into Lake Champlain at Blairs bay, produced the present composite lake, with its precipitous mountainsides and wild rugged scenery. The old relations are greatly obscured by the glacial drift. Schroon Lake is another ponded and drowned river valley, with both a sluggish outlet and a sluggish inlet, the former with wonderfully developed terraces on either side, running like railway embankments as they mark old periods of high water. The other notable series of lakes, like the Fulton Chain, have been produced by the drift in the old valleys, which were the great drainage lines before the glacial epoch. With moderate portages they can be navigated long distances.

Some of the smaller lakes are in fault valleys and not infrequently are on the divides so as to be the sources of the streams. The Cascade lakes (Fig. 7) between the Keene Valley and Lake Placid are good illustrations. Although now two, they were once continuous and have evidently been divided by a landslide.

The Ice Invasion of the Glacial Epoch.—Coming after so long an interval during which the Adirondack area was land the Labradorean ice sheet possesses exceptional interest. All the scratches so far observed and recorded point to a source on the northeast. The glacier advanced from this quarter, and, as has been shown in some detail by Dr. I. H. Ogilvie, rode over the highest mountains and apparently filled the valleys with stagnant ice, since, except in the borders, scratches are rare. In fact the Paleozoic strata, in the lower confines, where the Champlain clays soon buried and preserved the scratches, are the most prolific sources of observations. The hard Precambrian rocks have mostly lost them by weathering.

The ice sheet must have found the Adirondacks covered with a heavy mantle of the products of decomposition. The long time during which the mountains had been land could have had no other result than this. It also found them of rugged topography much as now, because if we believe or assume, as is reasonable, that the Cretaceous peneplain was broken up into the flat-topped blocks by the preglacial faulting, the region must have presented a very irregular barrier in the pathway of the ice. The ice has left not a few characteristic topographic forms as the result of its action. Cirques appear on the flanks of several of the higher mountains, as, for example, on the northwestern side of Giant and the eastern side of Whiteface. Projections of the ridge run out in each case at right-angles to the main axis, affording

a depression which must have had its own small glacier on the waning of the ice. This small glacier has eaten back against the main ridge so as to leave the characteristic cirque with its precipitous head.

Near Mt. Marcy, in the Paradox Lake quadrangle, Dr. Ogilvie has noted very perfect and striking cases of small rock basins, which the writer has seen under her guidance. Each is occupied by a small mountain lake, and is a bowl produced by plucking and scoring. Giant kettles or potholes are to be seen in many places around the northern shores of Lake George, and more particularly two or three miles north of Hague, where they are locally called Indian Kettles. There must have been sinkholes in the ice sheet at these points, which are now above the level of the lake, and torrents poured into them until the moulin or mill was established.

While moraines and huge transported boulders are not altogether lacking, yet they favor special localities and, generally speaking, the boulders are of but moderate size. The Potsdam sandstone furnishes a material of special interest, since it can be easily recognized, can be referred to its parent ledges and is found all over the mountain tops. The larger boulders are a quite marked feature to the west of Schroon Lake Post Office, and from a distance resemble small houses. One now cleft in twain near Hague, on Lake George, is fully thirty feet in diameter (Fig. 13). With the waning and retreat of the ice, lakes were impounded in not a few of the valleys and their surfaces reached to altitudes high above the present bottoms. Near Elizabethtown in the valley of the Boquet River, and in the Keene Valley along the east branch of the Ausable River the deltas formed by tributary streams are still very clearly preserved, cut in two as is usual by the downward erosion of the present stream. Ice must have largely formed the barriers. Other and usually small lakes, as has been noted by Professor C. H. Smyth, Jr., have reached the state of morasses or meadows, affording the so-called vlies of the early Dutch settlers.

With the waning of the great ice sheet the vegetation crept northward, covering moraines, sand-plains and hills with a coat of green. At first obviously Arctic in character as the little colonies of hardy plants still holding out on the mountain tops show, the flora and silva assumed gradually a more temperate aspect and prepared the Great North Woods to be the chief recreation ground for the people of New York and neighboring states.

THE BLACK LOCUST TREE AND ITS DESPOLIATION.

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WITHIN the past few years an increasing interest has been manifested in the black locust tree, *Robinia pseudacacia*. Many persons have begun to propagate it, not only as a wayside tree, but as a forest product; and issues of the public press lately have contained many articles and paragraphs pointing out the excellent qualities of the wood and recommending its general cultivation for economic uses. Several of the articles referred to have mentioned the fact that one of the great railroad companies has, within the past two years, planted on its Pennsylvania lands nearly a million and a half of trees of this species with the intention of using the product for railroad ties and fence posts, and for other purposes requiring exceptionally durable wood. It has been publicly announced that large additions to that company's planting of this tree are to be made, and it is also known that many smaller, but still extensive, enterprises of this kind, under both corporate and individual management, are in progress in different parts of our country. The aggregate of these enterprises requires the expenditure of so much labor and money before any profitable returns could be expected, that one who is acquainted with the past history of the tree can not but wonder at the apparent lack of business precaution, or of sound advice, which they imply. The fateful destiny of this tree has been long known and until recently it has been generally neglected; but by most persons the facts concerning it apparently are now forgotten or disregarded. From personal observations, extending through many years and over a large part of the United States and adjoining parts of Canada and Mexico, I am convinced that all attempts to cultivate this tree in any part of North America, with the possible exception presently to be mentioned, will result in failure so far as suitable returns in practical value of the product is concerned. The subject therefore has, with comparative suddenness, become of public importance, and my chief object in writing this article is the utterance of a public caution concerning it, especially directed to industrial interests.

The excellent quality of the wood of this tree is all that has been claimed for it, and doubtless it is this quality, together with the knowledge of the vigor of its early growth, that has encouraged the extensive preparations that lately have been made for its artificial propaga-

tion. Our soils and climate are almost everywhere well adapted to its growth, its abundant seeds germinate readily, and it responds promptly to the forester's care. The danger of failure in growing this tree for economic uses lies, not in the character of the tree nor in that of our soils or climate, but in the persistent attacks of destructive insects which are natives of the same region with the tree, which follow it in its geographical distribution, and which presently will be further referred to.

There are two North American trees which bear the popular name of locust, the one already mentioned and the honey locust, *Gleditschia triacanthus;* but it is only the black locust that is referred to in these remarks. This tree originally was known only in that region which lies east of the Allegheny Mountains and between New York and Louisiana. By natural dispersion and artificial propagation, however, it has grown for many years more or less commonly, but for the most part unthriftily, in nearly all the eastern half of the United States, as well as in other parts of North America. Early after its first discovery its seeds were carried to other countries, where the tree was successfully progagated from them. In Europe, especially, where its American insect despoilers never have been introduced, where the indigenous insects never molest it, and where it readily adapts itself to the local climatic and terreous conditions, it has always grown thriftily and symmetrically, reaching a maximum size comparable with that of the oaks. Being there esteemed as an ornamental tree, it is often grown in public parks, and it is also much cultivated in preserved forests for its valuable wood.

This European experience with the black locust tree well illustrates its extraordinary vigor and its ability to reach full maturity of growth under a wide diversity of conditions of soil and climate. Its completely successful growth to trees of medium size in formerly isolated North American districts west of its native regional habitat, and its persistent struggle for existence against its insect despoilers wherever it has been established in our country show that our soil and climate are entirely favorable to its growth and that it is only accessory, but dominant, conditions that are unfavorable. These accessory conditions are now known to be the result of ravages upon the living parts of the tree by the insects referred to. Indeed this tree presents the remarkable case of a strong arboreal species doomed on its native ground and in contiguous regions, to a constant state of suppression of its natural development, and even to local extermination, by insect despoilers which are natives of the same region with the tree and wholly dependent upon it for their own existence. There is no other North American tree, perhaps, excepting the common mezquite of our southwestern states and Mexico, which is so disastrously damaged in its growing condition by indigenous insects as is the black locust, and both of these trees

would be of very great industrial value if it were not for the ravages of those insects. Other insects, the imported gypsy moth for example, commit their terrible ravages upon the foliage of different kinds of trees indiscriminately, but the insect pests of the black locust and the mezquite are indigenous, and each species attacks only its own destinate tree. The chief injury to each of these trees is done by the larvæ which burrow in its living wood.

There are at least three species of insects which injure the black locust tree. The small larvæ of one of them tunnel the parenchyma of the leaflets, and another species produces a gall-like enlargement of the tips of tender twigs as a result of depositing and hatching its eggs there. But worst of all, the large, vigorous and abundant larvæ of one of the longicorn beetles, *Cyllene robiniæ*, burrow throughout the wood of the entire trunk and larger branches, rendering it unfit for economic uses. All these insect species are known to be dependent for their own existence upon the black locust tree because all three of them deposit their eggs nowhere else than in its tender tissues; all three of them pass their entire larval stage, the only stage in which the insect really increases in growth, in its living substance, and all three of them derive their only incremental nourishment from that tree. If, therefore, the black locust tree were exterminated, all those insects would necessarily perish; and if all those insects were first exterminated we should have restored to us one of the most valuable of our forest trees. But none of those contingencies is likely to occur.

Great damage is sometimes done to the black locust tree by the two insect species first mentioned, but usually their depredations are so much less disastrous than are those of the tree borer that, for only the present occasion the two former species may be regarded as negligible and only the latter need be specially noticed. Because this article is written with reference to a matter of public interest it is thought desirable to give a brief popular account of the characteristics and habits of that destructive insect. The beetle, which dies naturally soon after the function of reproduction is completed, is nearly an inch long, somewhat slender, and has a pair of slender curved antennæ as long as the body; and the larva is a vigorous grub nearly or quite as long as is the beetle. The metamorphosis from the larva to the pupa stage and from that of the pupa to the imago or beetle stage occurs as the insect is about to emerge from its burrow in the tree; the final change and emergence beginning to occur in late summer and continuing through autumn. The beetles soon mate and hover about the Solidagoes and other late flowers, feeding scantily and harmlessly upon the pollen. The females immediately seek the black locust trees by flight, pierce the bark and deposit their eggs in the soft cambium layer beneath it. The resulting larvæ burrow at once into the tree, traversing the wood of the trunk and larger branches in all directions. The insect there completes

the annual cycle of metamorphoses and emerges as a beetle of that generation about a year after the egg is hatched. The burrows are made by the strong horny jaws of the larvæ, which shred every particle of the wood in the course of the burrows, all of it passing through the intestinal canal of the larvæ. Only the scanty protoplasmic contents of the wood cells, however, are digested for nourishment, and the dry refuse, resembling fine saw-dust, is packed behind the larva as it progresses in its burrow. The burrows are comparatively large and when numerous, as usually they are, they cut across the wood fiber so frequently that the trunk and larger branches are often completely riddled by them.

Such is the condition to which the wood of the black locust tree is habitually reduced by those insects and to which it is the special object of this article to call public attention. It is almost needless to add that such burrows render the wood useless for timber, of little value as fuel, and more subject to decay than is the uninjured wood. Many and various kinds of insects burrow in the dead wood of different kinds of lumber and fuel and thereby do much injury, but comparatively few species bore exclusively in living wood, and these are extremely injurious. The destructive borer of the locust tree and the smaller but hardly less destructive borer of the mezquite tree, already mentioned, are two of the best-known examples of the latter kind. Perhaps the best-known example of the former kind is the hickory wood borer, which householders often find in their fuel; especially that which has been felled in late winter or early spring. These borings in hickory wood are closely like those which are made in the living locust trees, and the locust and hickory borers are so nearly alike in appearance in all three of their metamorphoses that it is difficult for the ordinary observer to distinguish them apart. The hickory borer, however, burrows only in recently felled dead hickory wood, its incubation therein beginning in the spring; while the locust borer burrows only in the living wood, its incubation beginning in late summer and continuing until frosts prevail. This last-mentioned fact is important with reference to any remedies against the ravages of the locust borer that may be proposed. Hickory wood which is felled in autumn or early winter is likely to escape its borers by becoming too dry to serve their needs when they reach the beetle stage in the spring; but for the locust tree, after its sapling stage, there is no immunity from its borers so long as it lives.

Apparently there are several reasons why the ravages of the locust borer have largely escaped popular attention, such as the destruction of fruit and foliage by insects receives. The bark of the tree usually remains intact long after the wood beneath it is greatly injured. The small pits and punctures which are made in it by the female beetle for depositing her eggs are not ordinarily noticeable, and even the holes by

which the beetles escape from the burrows are not conspicuous. While the bark remains unbroken the tree lives and usually continues annually to produce its seed. The latter fact not only belies its hidden trouble, but it is characteristic of the strong vitality of the tree. This vitality is also exhibited by the roots which send up vigorous suckers, especially after the borers have attacked the trunk. Again, the reciprocal relation of the tree and the insects which prey upon it, although it is never wholly interrupted, is of more or less unstable equilibrium, sometimes the tree, and sometimes the insects being ascendant. That is, it has often happened in a given district that the tree became reduced in numbers to a few scattered and injured specimens, and its insect enemies were correspondingly reduced in numbers because of the reduction of their only means of subsistence. The native vigor of the tree then gives it such advantage that it so thrives again that one naturally hopes for its permanent immunity. But that improved condition of the tree itself invites, and sooner or later receives, renewed attacks of the insects, which lurk there or which come in from contiguous districts. Such an oscillation of relative conditions occurs with the borer especially, thus deceiving local observers as to the great average damaged condition of the tree. The two insect species which have been mentioned as preying upon the leaves and tender twigs respectively have their needs supplied by even the youngest, as well as the older, growth of tree, but the borer requires a body of living wood of some inches in diameter in which to produce burrows of sufficient extent for its needs. Therefore this greatest of the insect enemies of the black locust tree is held at bay until the tree has reached sufficient size for boring, during which time the planter must await the issue. Meantime the young of this tree generally grows as thriftily as the average of other trees, and often it produces seed before it is large enough for the borers. It is not strange that this early thrift of the tree should encourage disbelief of impending evil for it, but the facts here mentioned are too well established to admit of serious question.

Exceptionally large and healthy specimens of the black locust tree are sometimes found growing as a part of the native arboreal flora, their, at least partial, immunity from insect injury doubtless being due to local causes, some of which are obvious and some obscure. For example, some of the best American specimens of the tree are found to have grown in, or around, cattle-pens, barnyards or other farmstead inclosures where domestic animals are gathered, the conditions of which places are known to be favorable to the tree, and they are apparently unfavorable to the insects. Again, the isolation of the tree by planting its seeds in districts remote from those in which both the tree and its insect enemies prevail, has resulted in the healthy growth of the tree for many years; but in most of such cases the trees have been overtaken by the borers and destroyed or rendered valueless

long before they could have reached the full size of which the species is capable. My present information indicates that there are yet some districts in the western part of the United States, notably portions of California, in which the black locust tree, which was originally grown there from eastern seed, has not yet been injured by the borers. But the borers are surely lurking in all other parts of our country in which that tree has grown for any considerable number of years. Furthermore, judging from the facts already stated and the remarkable case of destruction of that tree by the borers which occurred in the great valley of the Upper Mississippi between forty and fifty years ago, one may reasonably fear that those farther western groves will yet suffer like disaster.[1]

The case referred to is peculiar, and fraught with important suggestions to those who are now contemplating the artificial propagation of the black locust tree. In the early half of the past century there occurred a strong migratory movement of families overland from eastern states to Illinois and Iowa, who carried with them in their wagons the seeds of various kinds of trees, among which were those of the black locust. Those seeds were planted in the fertile soil of the new homesteads, where they germinated promptly and the seedlings grew vigorously and healthfully. The settlers thus 'stole a march' of many hundred miles on the borers, for neither they nor the tree upon which they exist had then occupied a large part of the country which the emigrants traversed. The seedling trees of the earlier settlers soon reached reproductive maturity and furnished abundant seed for further planting. The streets of the towns and villages were bordered with the trees and the farmers who possessed prairie land planted groves of them with the expectation of using the product for much-needed fence posts, and for other purposes. But while the trees were rapidly increasing in size by healthy growth, ominous reports began to reach the settlers that the borer was moving westward and, finally, that it was approaching the great region in which they had made their homes. In due time the borers arrived there, for the intervening country eastward had become so dotted with artificial groves of the black locust tree that the insects in their beetle stage, easily spread from grove to grove by natural flight. None of those trees in the Mississippi valley had then reached the maximum size of the

[1] A personal communication from Mr. A. E. Schwarz, of the U. S. Department of Agriculture, who has long made special studies of the habits of these insects, confirms my own observations as to the extent and imminence of their ravages. He thinks, however, that the Locust borer possibly may not invade our Pacific Coast region because the insect fauna there being so different from that of which the borer is an original member is likely to prevent its geographical range over that region. He thinks it probable also that a similar faunal influence has prevented the introduction of the borer into Europe, where the tree has been so fully acclimated.

species, but they had fruited for many years, and some of them had reached a foot or more in diameter at the base. They had grown so thriftily that their continued growth was naturally expected by those who had planted them; but when the borers came the trees were everywhere injured or destroyed as by a pestilence. Within a very few years after the first appearance of those insects in that western region nothing remained of the almost numberless groves and rows of those trees except their blasted remnants and the young shoots that the vigorous and unconquered roots were striving to bring forth. That condition remains there to this day, essentially unchanged except that even the stumps and roots of the blasted trees have, from time to time, been removed to reclaim for other uses the soil which they formerly occupied. Because of that wide destruction one may now go many miles in that great region without seeing more than a few neglected outcasts of that once popular tree; just enough to afford breeding places for a few of the hardy and prolific borers, which are always ready to commit their ravages. I was an eye-witness of that great destruction from its beginning to its consummation, and afterward had unusual opportunity to observe its effects when investigating the subject of foresting the prairie soils of Iowa. Similar destruction also occurred as the borers traversed the country between their native region and the Mississippi valley, the effects of which still remain there.

The question now arises whether there is any known remedy for the attacks of those insects. Unfortunately no effective remedy of general applicability has yet been discovered. The attacks of the insects are not upon any of the parts concerned in reproduction, such as might interfere with the propagation of the tree, but upon its growing substance, which is constantly exposed at all seasons of insect activity. Therefore its inflorescence and fruitage need no protection, and proposed remedies must be applied to the surfaces of the tree and directed against some important function in the life of the insect, mainly that of reproduction. The killing of the insects in any considerable numbers seems to be quite impracticable. The few remedies which have been proposed are fluid applications which are harmless to the trees and so repugnant to the insects that they will not puncture any surface to deposit their eggs which has been so covered. But many difficulties attend the application of such remedies. The leaves and terminal portion of the twigs are doubtless too delicate for such treatment, but the bark is not easily injured by it. The application with a brush to the bark of the trunk and branches of lime whitewash mixed with a solution of whale-oil soap has seemed to prevent the female of the borer in the beetle stage from puncturing the bark to deposit her eggs. But to be effective all such applications must carefully be made to the entire surface of the trunk and to that of the branches which have reached a couple of inches or more in diameter. They must

be applied not later than midsummer, that is, before the newly matured beetles have begun the function of reproduction, and they must be continued intact until frosts have killed the last of the beetles for the year. They also must be renewed annually as long as the tree stands. One might feel justified in employing such a remedy to save a few favorite trees, but it involves too much labor to be of practical value for general application.

The foregoing statements, which are assumed to be indisputable, show that the prevailing condition of the black locust tree in the land of its origin warrants the conclusion that it is fated, not to extinction, but to destruction as a profitable natural product; and that this fate is beyond the effective reach of any known general remedy. The biological aspect of this subject is one of very great interest, but this article has purposely been confined to a presentation of its economic bearings, the significance of which is too obvious to need explanation.

A CONTRIBUTION TO THE THEORY OF SCIENCE

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ONE of the few points on which the philosophy of to-day is agreed consists in the realization that the only thing that is absolutely certain and beyond doubt for every one is the content of his own consciousness; or rather not so much the content of consciousness in general as merely the content of any given moment.

This momentary content we divide into two great groups which we assign to the inner and to the outer world, respectively. If we call a single content of consciousness of any kind an experience, we refer such experiences to the external world as take place without the participation of our own will and which can not be produced by it alone. Such experiences come to us through the participation of certain parts of our body, the sense-organs; the external world, in other words, is that which reaches our consciousness through the senses.

Conversely, we refer to our internal world all the experiences which come to pass without the immediate help of our sense-apparatus. To this class belong all the experiences which we designate as 'remembering' or 'thinking.' An accurate and complete differentiation of both territories is at present not contemplated because it is not yet necessary. It is a problem which is not capable of being attacked and solved until later. For the present a general orientation in which every man may recognize the familiar facts of his own consciousness is sufficient.

Each and every experience has the property of being unique. None of us doubts that the words of the poet: 'Everything in life repeats itself,' strictly speaking, is the opposite of the truth, and that, as a matter of fact, nothing in life repeats itself. In order, however, to pronounce a judgment of this kind we must be in a position to compare different experiences with one another; and the possibility of doing so depends upon a fundamental phenomenon of our consciousness, 'memory.' By virtue of memory alone, are we able to bring different experiences into relation with one another, and thus make it possible to propound at all the question concerning their likeness or difference.

The simpler relations are to be met with among internal experiences. Any given thought, such as twice two are four, I am able to produce in my consciousness as often as I choose; and, in addition to the con-

[1] Address before the Section of Methodology, Congress of Arts and Science, St. Louis, translated by Dr. Carl. L. Alsberg.

tent of the thought, I have the further consciousness that I have already had this thought, that it is familiar to me.

Similar, though somewhat more complicated, is the phenomenon in the case of experiences in which the external world had participated. After eating an apple, I may repeat this experience in two ways. I may repeat it as an inner experience, though with diminished intensity. Another part, the sensations that formed a piece of my experience, I am unable at will to reproduce in myself; but am compelled again to eat an apple in order to have a similar experience in this respect as well. This is a complete repetition that it is not necessarily in my power to produce because it is essential that I have an apple, *i. e.*, that certain conditions belonging to the external world and independent of myself be fulfilled.

Whether in the repetition of an experience the outer world takes part or not has no influence upon the content of consciousness, called 'memory.' It follows, therefore, that the latter belongs wholly to internal experience, and that we remember an external event only through its inner constituents. The mere repetition of corresponding sense impressions is not sufficient. We may see the same individual repeatedly without recognizing him in case the accompanying inner phenomena have, through lack of interest, been so slight that their repetition does not produce this content of consciousness, 'memory.' If, however, we see him very often, the frequent repetition of the external impression finally produces the memory of the inner experience that goes with it.

Hence it follows that to call forth the reaction, 'memory,' a definite intensity of the internal experience is necessary. This threshold value may be attained either at one time by one strong impression, or by numerous repetitions of weak ones. The repetitions are the more effective, the more rapidly they follow upon one another. Hence we may conclude further that the memory value of an experience, or its power upon repetition to call forth the reaction, 'memory,' diminishes in the course of time.

Furthermore we must take into consideration the above-mentioned fact that a completely accurate reproduction of an experience never takes place. The reaction, 'memory,' must therefore be called forth when in place of complete correspondence there is merely similarity or partial correspondence. Here, too, there are gradations. Memory appears the more easily, the more completely the two experiences correspond; and *vice versa*.

If we look at these relations from a physiological point of view, we are able to say: We possess two kinds of contrivances or organs, of which one is independent of, and the other dependent upon, our will. The former are the organs of sense, the latter is the organ of thought.

Only activity of the latter forms our experiences or the content of our consciousness. The participation of the former may call forth corresponding processes in the latter, though this is not always necessary. Our sensory apparatus may be influenced without our 'noticing' it, *i. e.*, without the participation of the apparatus of thought. A particularly important reaction of the thought apparatus is 'memory,' *i. e.*, the consciousness that an experience just taking place corresponds more or less with former experiences. It is the peculiar expression by the apparatus of thought of the general physiological law that every process influences an organ in such a way that it reacts to a repetition of this process in a way different from its reaction the first time, namely, by facilitating repetition. This effect decreases in time.

Upon these conditions experience in the abstract is based and is the result of the fact that experiences are composed of a whole series of simultaneous and successive components. If, as the result of the repetition of similar experiences (for instance the sequence of day and night), we have become familiar with the interdependence of certain experiences, we no longer perceive such an experience as an entirely new one, but rather as in part familiar, so that its separate parts or phases no longer astonish us. We anticipate or expect them. From expectation to prediction is but a very short step. Thus experience enables us to prophesy the future from the past and the present.

This is the path to science which is nothing other than experience systematized, that is to say, reduced to simple and comprehensible terms. Its aim is to predict from the known part of a phenomenon the part that has remained unknown. It matters not whether we have to deal with phenomena of space or of time. Thus from a skull the scientific zoologist is able to determine the animal; that is to say, he is able to state the nature of all the other parts of the animal to which the skull belonged. In the same way an astronomer on the basis of a few observations of the position of a planet, is able to foretell its future position. He is able to do so for a future the more remote the more accurate his original observations. All such scientific predictions are limited in regard to their content and exactness. If the skull presented to the zoologist be that of a fowl, he is able to state the characteristics of fowls in general, perhaps too whether this particular fowl possessed a comb or not. He will be unable to tell its color and only within wide limits its age or its size. Both facts, the possibility of prediction and its limitations as regards content and extent, are expressions of the fundamental fact that our experiences may be similar, but are never completely identical.

These preliminary considerations need to be explained and enlarged upon in various directions. One may object to calling a fowl or a planet an experience. We call them by the most universal name—

things. However, our knowledge of fowls always begins with the experience of certain sensations of sight with which sensations of hearing and of touch may be associated. The sensations of sight, to which we will limit ourselves for the present, are by no means completely identical. According to its distance from us, we see the fowl as large or small; with changes in its position and its movements its contour is very different. As, however, we observe that these differences pass continuously into one another without exceeding certain limits, we overlook them and confine ourselves to certain other peculiarities (legs, wings, eyes, beak, comb, etc.) which remain constant and do not change. The constant properties we gather together as a 'thing': the changing ones we call the states of this thing. Among the changing ones we distinguish those which are dependent upon ourselves (*e. g.,* distance) from those upon which we ourselves have no immediate influence (*e. g.,* position and movements). The former we call the subjectively variable part of our experience, whereas we term the latter the objective variability of the thing.

To ignore the subjectively and objectively variable portion of our experiences, while we retain their constant parts, and to combine the latter into a single unity, is one of the most important operations which we base on our experiences. We term this procedure *abstraction,* and its product, the constant unit, a *concept.* Obviously this procedure contains arbitrary as well as essential parts. Quite arbitrary, or rather accidental, is the fact that according to the state of our attention, our training, nay even our whole intellectual make-up, quite different parts of any given experience reach our consciousness. We may overlook constant components and notice changing ones. But all components become of necessity objective as soon as we have noticed them. After once seeing the fowl black, it is no longer in our power to see it red. It follows that in general our knowledge of corresponding characteristics is less extensive than it might be, inasmuch as we have never noticed all that correspond. Our concept is, therefore, poorer at any given moment in components than it might be. To search for these hitherto overlooked components of a concept and to prove them a constant part of the corresponding experience is one of the never-ceasing labors of science.

The other possibility, *viz.,* that certain components which do not prove to be constant have been incorporated into a concept, also occurs and leads to another problem. These questionable components may, on the one hand, be eliminated from the concept if further experiences show that the remaining ones are contained in them; or, on the other hand, a new concept may be formed by including the constant components and eliminating the inconstant ones. Thus for a long time the white color was a part of the concept 'Swan.' When the black swans of Aus-

tralia were discovered it was necessary either to eliminate the component 'white' from the concept 'swan' (as was actually done) or else to create a new concept for the bird which resembled a swan, but was black. Which course is decided upon is to a great extent arbitrary, and determined by considerations of fitness.

We have then two factors participating in the formation of a concept, one objective, the result of experience; and one subjective, dictated by fitness. The fitness of a concept is adaptation to the purpose to which it is to be put, and it is this case that we must now consider.

The purpose of a concept is its application in prediction. Ancient logic established the syllogism as the type of the process of thinking, the simplest example of which is the familiar:

> **All men are mortal;**
> **Cajus is a man;**
> **Therefore, Cajus is mortal.**

The universal formula is:

> **To the concept *M* belongs the component *B*;**
> ***C* is included in the concept *M*;**
> **Therefore the component *B* is found in *C*.**

It may be said that this method of reasoning has remained in use up to the present day. We must, to be sure, add that its application is of a sort quite different from its ancient one. While formerly propounding the major premise was considered the more important, and the propounding of the minor premises was regarded as an almost self-evident and easy matter, to-day the relations have been reversed. The major premise contains the description of a concept, the minor makes the assertion that a certain thing must be classed under this concept. What justification is there for such an assertion?

The most evident answer is that because all the components of the concept *M* (including *B*) are to be found in *C*, *C* must be classed under the concept *M*. A conclusion of this kind would certainly be true, but at the same time quite valueless, for it only repeats the assertion of the minor premise.

As a matter of fact, our method of drawing conclusions is essentially different, for the minor premise is not obtained by proving all the constituents of the concept *M* to be present in *C*; but only some of them. The conclusion is, therefore, not binding, but merely probable. The whole method of drawing a conclusion is as follows: Certain constituents frequently occur together. They are combined to form the concept *M*. In the thing *C* some of the constituents may be recognized. Therefore, presumably the other components of the concept *M* occur in *C*.

Ancient logic was also familiar with this method of reasoning; but it was branded with the name of incomplete induction as the worst of all because it lacks absolute and unconditional certainty. One must admit, however, that all contemporary science makes use of no form of reasoning other than incomplete induction. It alone permits of prediction, that is to say, the determination of relations which have not yet been directly observed.

But how does science get along with this lack of certainty in its method of drawing conclusions? The reply to this question is that the probability of the conclusions may run the gamut of all possible gradations from mere supposition to the maximum of probability which is no longer to be distinguished, practically, from certainty. The probability is greater the more frequently any given incomplete induction of this kind has been found consistent with subsequent experience. Thus we have at our disposal a number of propositions which in their simplest and most general shape take the form: If the component *A* is to be found in a given thing, the component *B* is also to be found in it (in relation to either time or space).

If the relation is one of time, we term this general proposition the law of causality. If it is one of space we speak of the idea (in the Platonic sense) or type of the thing, of substance, etc.

These considerations yield answers to many questions which have been repeatedly propounded in various forms. We have first the question of the universal validity of the law of causality. All attempts to establish this kind of validity have failed, and only the fact remains that without this law we should feel an unendurable uncertainty as to the world. Hence it follows that we have to deal in this matter with a question of fitness. From the constant stream of our experience we select relations which we encounter again and again in order that whenever the component *A* is given us we may conclude that the component *B* is also to be found. Hence we do not find these correlations occurring as 'given,' but we ourselves bring them into our experiences, by ourselves regarding the components which show such a connection as belonging together.

We may make quite the same statements in regard to space relations. The components which are always, or at any rate frequently, encountered together we interpret as forming a unit; and we shape from them a concept which includes these components. As in the case of time relation, there is no sense in propounding the question *why*. There are thousands of correlations to which we pay no attention because they are unique or rare. Knowledge of such a unique correlation leads to nothing, because it does not enable us to infer the presence of one component from the presence of another and therefore does not render prediction possible. Of all possible and actual combina-

tions only those interest us which are repeated. This arbitrary though fit selection creates the impression that these are the only recurring combinations, or that, in other words, the law of casuality or of type rules unqualifiedly. How universal or how limited is the application of these laws is therefore rather a question of our skill in selecting the constant combinations from among all those occurring than a question of objective natural phenomena.

Thus we observe the development and practise of all sciences progressing in this manner by the discovery, on the one hand, of ever more numerous individual constant combinations, and, on the other, of more and more universal laws by means of which components are brought into relation with one another, which formerly no one had attempted to bring together. Thus sciences grow in that they become *complex* and at the same time *unified*.

If now we consider the development and course of the various sciences from this point of view we shall attain a rational classification of all science by an inquiry into the extent and complexity of the combinations or complexes which they treat. Both characteristics are in a sense antagonistic. The simpler a complex is, that is, the fewer the components united in it, the more frequently will it occur; and *vice versa*. It will therefore be possible to classify all the sciences in this fashion by beginning with the minimum of complexity and the maximum of extent and ending with the maximum of complexity and the minimum of extent. The first science will include the most general and therefore the poorest and most meager concepts; the last the most specialized and therefore the richest.

What then are these limiting concepts? The most universal is the thing, any fraction of experience arbitrarily selected from the stream of our experiences and capable of repetition. The most specialized and the richest is the concept of human society. Between the study of things and the study of human society all the remaining sciences may be interpolated in an orderly series. The attempt to follow out this scheme leads to the following table:

1. Science of manifoldness or assemblages, Logic.

2. Science of numbers or arithmetic,
3. Science of time,
4. Science of space or geometry,
} Mathematics.

5. Mechanics,
6. Physics,
7. Chemistry,
} Energetics.

8. Physiology,
9. Psychology,
10. Sociology,
} Biology.

This table contains an arbitrary element inasmuch as the steps assumed in it may be multiplied. Thus mechanics and physics might

be combined or physical chemistry interpolated between physics and chemistry. Similarly anthropology might be placed between physiology and psychology while the first four sciences might be combined as mathematics. How this subdivision is to be carried out is purely a practical question which will be answered differently by different ages and concerning which it is useless to quarrel.

I would like, however, to call attention to the three great divisions: Mathematics, energetics and biology (in the broader sense). They represent the three guiding thoughts which up to the present mankind has brought forth for the purpose of mastering scientifically its experiences. *Order* is the fundamental thought of mathematics, *energy* the guiding concept from mechanics to chemistry; for the last three sciences it is *life*. Mathematics, energetics and biology therefore embrace the whole body of the sciences, while logic precedes them all.

Before entering upon a more detailed consideration of these sciences, it is well to anticipate an objection which may be raised on the basis of the following fact. There are in addition to the previously mentioned sciences (as well as the intermediate ones) many others such as geology, history, medicine, philology, which present difficulties if a place is sought for them in our scheme, and which, nevertheless, demand consideration. It is often characteristic of them that they bear relation to several of the sciences which have been enumerated; and still more characteristic of them is it that they do not search for universal relations as do the pure sciences, but rather treat existing complex objects in order to 'explain' or discover their origin, extent, distribution, in a word their time and space relations. To accomplish this object they make use of the relations which the pure sciences have put at their disposal. It is best to designate these sciences as *applied* sciences. This term is not meant to imply either exclusively or even chiefly technical application. It is merely intended to express the fact that here interrelations of the parts of a ready-made object are rendered intelligible by the application of the general laws which have been discovered by pure science.

In a problem of this nature it is usually necessary to make use of several different pure sciences simultaneously for an explanation, because the abstract method of the pure sciences is not permissible here. To omit certain parts and to limit oneself to certain others is from the very nature of the problem out of the question. Astronomy is an applied science of this sort. It is based immediately upon mechanics; in its instrumental part upon optics; while in its contemporaneous spectroscopic development it borrows much from chemistry. Thus history is applied sociology and psychology; medicine makes use of all preceding sciences up to psychology, etc.

It is important to realize the nature of these applied sciences since

their composite nature renders it impossible to classify them among the pure sciences, though, because of their practical importance, they demand consideration. The latter characteristic gives them to a certain extent an arbitrary or accidental character since their development depends upon the particular requirements of the times. Their number, broadly speaking, is very great because every pure science may be changed to an applied one in many ways and may be combined for this purpose with one or more other sciences. Furthermore, the method of applied science is fundamentally different from that of pure science inasmuch as the former seeks to analyze any given complex into its scientifically manageable parts, whereas conversely the latter considers many complexes in order to extract from them their common feature and explicitly refrains from the complete analysis of each individual complex.

In scientific work, as carried out in practise, pure and applied science are by no means always to be sharply separated. On the one hand, the means of research, apparatus, books, etc., demand the knowledge and the practise of applied science even by the 'pure' investigator. On the other hand, the 'applied' investigator is often able to solve his problem only by becoming temporarily a 'pure' investigator and himself ferreting out or discovering the universal relations which he needs for the solution of his problem. The separation and differentiation of these two kinds of science was, however, necessary, because each employs quite different methods and pursues essentially different ends.

In order that we may attain a clear understanding of the method of pure science, we will turn to the table on page 225 and consider the individual sciences separately. The first place is ordinarily given to mathematics as to the science of quantity. However, mathematics deals with number and size as its fundamental concepts, while the science of assemblages does not as yet use them. Moreover, in the latter, the fundamental concept is the thing or object of which no more is required than merely that it be a fraction of our experience capable of being isolated and remaining so. It may not be any indiscriminate fraction, for such a one could have but a momentary duration; and the aim of science, to discover the unknown from what is given, could not be accomplished with it. This part of experience must rather be of such a nature that it may be distinguished and recognized, that is to say, it must already be of the nature of a concept. Only those parts of our experience which are capable of repetition (for these alone can form the subject-matter of science) can be called things or objects. This statement, however, includes everything that is required of them. Otherwise they may differ as much as is conceivable.

If it be asked what scientific statements it is possible to make concerning such uncertain things, one will find that the relations of

order and classification are the ones to yield results. If we designate any limited combination of things of this nature a group, we may arrange a group in different ways, that is, we may determine for each thing the relation in which it is to stand toward neighboring things. Such an arrangement produces not merely the relations prescribed above, but in addition a large number of new ones; and it becomes plain that, given the first relations, the others may be observed at once. This gives us the type of a law of nature: the possibility of inferring from the presence of a definite classification-relation the presence of others which we have not yet tested.

To illustrate by an example: Let us imagine the things arranged in a simple series formed by choosing one thing for the first member; placing another next to this one; then a new one next to the latter; another next to the last, etc. The position of each thing in the series is determined in relation to the immediately preceding one. Nevertheless the position of every member of the entire series is determined; and thus its relation to every other member. This fact appears in a number of special laws. If we distinguish between preceding and succeeding members one of the laws we may observe is: If B is a succeeding member in relation to A, and if C is a succeeding member in relation to B, then C is also a succeeding member in relation to A.

The correctness and universal validity of this proposition seems to us beyond any possible doubt. It depends, however, merely upon the fact that we are able to test it with the greatest ease in innumerable individual instances and have so tested it. We know none other than instances agreeing with this proposition and none that contradict. Therefore, to designate such a statement as a necessity of thought seems to me misleading. Now the expression necessity of thought can only be based upon the fact that each time one thinks this proposition, that is, remembers having tested it, one always has in mind its confirmation. Any wrong proposition is, however, conceivable as the fact that so much that is wrong is actually thought indisputably shows. To base the proof of the truth of a proposition upon the inconceivability of its converse is an undertaking that can not be carried out, because it is possible to think any sort of nonsense. Whenever this proof was believed to have been demonstrated, thinking was always confused with considering, demonstrating or proving.

Of course the theory of groups is not exhausted with this single statement. We do not, however, care to develop this theory here, but rather to give an example of the nature of the problems of science. Of the other questions only the method of coordination will be briefly treated.

Given two quantities A and B, one may assign to every member of A a member of B, that is, one determines that certain operations which

are to be carried out with the members of A, shall also be carried out with those of B. We may begin by simply associating them member for member. Then one of three things will happen: either A will be exhausted while members of B remain, or B is first exhausted, or finally A and B are exhausted simultaneously. In the first case we say that A is poorer than B; in the second B is poorer than A; and in the third case that both quantities are equal.

We meet now for the first time the scientific concept of equality; and it is necessary that we enlarge upon it. Absolutely complete identity of both groups is obviously out of the question, inasmuch as we made the assumption that the members of both groups might be of any nature whatsoever. Regarded singly they may be as different as possible. They are, however, equal as groups. For, however I arrange the members of A, inasmuch as a member of B is assigned to every member of A, I am able to carry out every arrangement of A upon B as well. As regards the possibilities of arrangement there is no apparent difference between A and B. As soon, however, as A is either poorer or richer than B, this similarity disappears, for one of the two quantities possesses members to which no members of the other groups correspond. The operations that may be performed upon these members can not be carried out upon the second group.

Equality, in the scientific sense of the word, signifies, therefore, equivalence or the possibility of substitution as regards definite operations or relations. In all other respects the things that have been pronounced equal may differ in any way. It is easy in this special case to recognize the universal method of abstraction of science.

It is possible on the basis of these definitions to make further propositions. If the quantity A is equal to B and if B is equal to C, then A is also equal to C. This may be proved by first arranging A with reference to B. According to our presupposition no member remains. Thereupon C is arranged with reference to B with no member remaining. In this way every member of A is, through the intervention of B, assigned to a member of C. Moreover, this arrangement remains unchanged even after the removal of B, *i. e.*, A and C are equal. The same method may be applied to any number of quantities.

It is possible to prove in a similar manner that, if A is poorer than B, and B is poorer than C, A must also be poorer than C. For in assigning the members of B to A, some members of B will, according to our assumption, remain, and the same will be true of C if we assign the members of C to those of B. Hence in assigning the members of C to those of A there are left not merely the members which can not be assigned to B, but also the members of C which have been assigned to such members of B as are supernumerary in respect to A. This proposition is applicable to all groups and renders it possible to arrange

different groups in a series by beginning with the poorest and choosing each succeeding one so that it is richer than its predecessor though poorer than its successor. Through a proposition that has been already proved (p. 229) it follows that each group is thus also arranged with reference to all other groups in such a way that it is richer than all its predecessors as well as poorer than all its successors.[2]

In developing most simple propositions or laws, this method of their discovery and the nature of the results become most clear to us. We achieve such a proposition by carrying out an operation and giving expression to its results. This expression enables us thereafter to save ourselves the trouble of repeating the operation. We are able to give the result immediately in accordance with the law. Thus we shorten and facilitate the procedure more or less according to the number of operations avoided.

Given any number of equal groups, we recognize that by arranging them with relation to one another as above, we are able to carry out upon all of them each and every operation involving arrangement that we are able to carry out upon one of them. It is therefore sufficient to determine the characteristics of arrangement of any one of these groups in order to know those of all the others. This is a most important proposition which is constantly applied for manifold purposes. Thus talking, writing and reading are founded upon the coordinating of thoughts to sounds and signs; and by arranging the signs in accordance with our thoughts we cause our hearers or our readers to think the same thoughts in the same sequence. We manipulate many formulæ in a similar manner (especially in the simpler sciences), applying the results to phenomena, instead of dealing with the phenomena themselves; and we are able to deduce some properties of the latter without being compelled to work with the phenomena themselves. The force of this procedure is most striking in astronomy, where, by manipulating certain formulæ which have been applied to certain celestial bodies, we are able to predict their future positions with a great degree of accuracy.

From the science of order we pass to the science of numbers or arithmetic by the systematic development of an operation that has just been indicated. We are able to arrange any given number of quantities in such a manner that the richer always succeeds the poorer. The system obtained in this fashion is, however, quite accidental as regards the number and richness of its members. Obviously we can only obtain an orderly structure of all possible groups by starting with a group having but one member, *i. e.*, a simple thing, and forming new members of the series from old ones by adding a single member. By this process we at once obtain the different groups arranged

[2] Equal groups can not be distinguished here; and represent merely a single quantity.

according to their richness. Further, inasmuch as we advanced by a single member, that is, we have made the smallest step possible, we are certain to have omitted no possible group that is poorer than the richest to which we have advanced our operation.

This whole procedure is well known. It yields the entire series of positive numbers—the cardinal numbers. It is to be noted that the concept of magnitude does not appear as yet. What we have obtained is merely the concept of number. The individual members may be chosen quite arbitrarily. They need in no way be equal. Each number represents a quantity type; and it is the sphere of arithmetic to examine these different types in respect to subdivision and combination. If this be done without considering the amount of the number, we call the corresponding science algebra. On the other hand, the extension of formal rules beyond their original application has led to one development of numbers after the other. Thus counting backwards leads to zero and the negative numbers, the square root of the latter to the imaginary numbers. The quantity-type of all the positive numbers is, to be sure, the simplest, though by no means the only possible one. For the purpose of representing other arrangements such as occur among our experiences these new types have proved very useful.

At the same time the numerical series yields a most useful type of arrangement. From its very origin it is arranged in an orderly fashion and it is therefore employed for the purpose of arranging other quantities. Thus we are accustomed to apply the signs of the numerical series to any objects which we desire to use in a definite order, such as the pages of a book, the seats in a theater, as well as countless other groups. We, however, tacitly make the assumption that the arranged groups are to be used in the same sequence in which the natural numbers follow one another. These sequence-numbers represent no magnitudes nor do they represent the only type of arrangement possible. They are, however, the very simplest.

We do not reach the concept of magnitude until we reach the science of time and space. A science of time has not been developed separately. On the contrary, what there is to say about time usually appears for the first time in mechanics. However, it is possible for us to state the fundamental characteristics of time here, so that the want of a distinct science of time will not be felt.

The first and most important property of time (and also of space) is that it is continuous. In other words, any portion of time may be divided at any point. In the numerical series this is not the case; it may be divided only between numbers. The series one to ten has nine places of division, and only nine. A minute or a second, on the other hand, has an unlimited number of possible points of division. In other words, there is nothing in the passage of time preventing us at

any desired moment from separating or distinguishing in thought the time that has passed from that which is to follow. Space is of the same nature, except that time is simple, space threefold.

Nevertheless, we are accustomed to describe both time and space by means of numbers whenever we measure them. If we examine into this procedure, for instance in the case of measuring length, we find that it consists in applying a length considered fixed, the measure, as often to the length to be measured as is necessary to cover it. The number of applications gives us the measure or magnitude of the length. It merely amounts to forcing an artificial discontinuity upon a continuous length by marking off arbitrarily chosen points, allowing us to refer it to the discontinuous numerical series.

The equality of the portions of distance set off by the measuring-rod is an essential part of the concept of measuring. We assume this condition fulfilled no matter how the measuring-rod be shifted. As we see, this is a more forced definition of equality than heretofore made, for it is actually quite impossible to substitute a given portion of a distance for another in order to become convinced that the validity of our definition is not impaired, that nothing is changed thereby. It is quite as impossible to prove that the measuring-rod in being shifted in space remains of the same length. We may only affirm that such distances as are determined in various places by means of the measuring-rod are declared or defined as equal. As a matter of fact, the measuring-rod in perspective looks smaller the further it is away from us.

This example demonstrates anew the great arbitrariness with which we shape science. It is conceivable that a geometry might be developed in which the distances are considered equal which subjectively appear to our eye to be so, and we should then be quite as able to develop a consistent system or science. A geometry of this kind would, however, be of too complicated a nature to be advantageous for any objective purpose (*e. g.*, surveying). Therefore we endeavor to develop a science as free as possible from subjective factors. Historically the Ptolemaic astronomy and that of Copernicus present an illustration in point. The former was formed according to subjective appearances in its assumption that the stars revolved about the earth. It proved most complicated when confronted with the problem of expressing these motions mathematically. The latter gave up the subjective point of view of the observer who regarded himself as the center; and, by transferring the center of motion to the sun, produced an enormous simplification.

A few more words are necessary at this point concerning the application of arithmetic and algebra in geometry. It is well known that under certain assumptions (coordinates) geometric figures may be expressed in algebraic formulæ so that it is possible to deduce the

geometric properties of the figures from the calculatory properties of the formulæ, and *vice versa*. We must inquire how such close and unambiguous relations can exist between things so diverse. The answer is that we have to deal in this instance with a particularly obvious case of association. The manifoldness of numbers is far greater than that of planes or space, for, whereas the latter are determined by but two or three independent measurements, any number of independent numerical series may be made to react upon one another. We therefore arbitrarily limit the manifoldness of the numbers to two or three independent series, and determine (by means of the cosinus law) their mutual relations so that a manifoldness corresponding exactly to that of the space arises to which we are able completely to refer it. We have then two manifoldnesses of identical character; and all properties of arrangement and size of the one are 'depicted' in the other. In this an extremely important scientific procedure is indicated which consists in giving to the experience-content of a given field a formal manifoldness to which we impart the same manifoldness-character as that possessed by the former. Every science thus develops a formula language of its own, perfect in proportion to the accuracy with which the manifoldness-character of the object has been recognized, and the fitness of the formulæ selected. Whereas, in arithmetic and algebra this problem has been solved quite perfectly (though by no means absolutely so), chemical formulæ, for instance, express only a relatively small part of the characteristics which they ought to express, while in biology and sociology we have hardly progressed beyond the very beginnings of the solution of this problem.

One of these universal manifoldnesses designed to express our experiences is speech. Inasmuch as it was developed in a primitive civilization it is by no means regular and complete enough to fulfil its purpose satisfactorily. On the contrary, it is quite as unsystematic as were the events in the history of the various peoples. The need to express the infinite variety of events in daily life has been filled by allowing word and concept to correspond only within a wide limit of variation. Therefore all research in the sciences which are forced to employ this means of expression (psychology and sociology or philosophy generally) is greatly impeded by the struggle with the indefiniteness and ambiguity of language. An improvement of these conditions is to be attained only by the introduction, as rapidly as the progress of the science warrants it, of symbols to which we refer the manifoldness which experience tells us is peculiar to the concept.

The sciences which have been classed above as a part of energetics occupy an intermediate position. In addition to the concepts of order, number, magnitude, space and time we meet in this branch of knowledge with the new concept of energy, which is applied as universally to

every phenomenon in this field as the other universal concepts. This is so because a certain magnitude, known to us immediately as mechanical work, may be proved to be a constituent of every physical phenomenon, *i. e.*, of mechanics, physics and chemistry, by virtue of its qualitative transformability, and its quantitative immutability. In other words, it is possible to characterize every physical phenomenon completely by stating what quantities and kinds of energy are present and into what kinds of energy they are transformed. It is, therefore, more rational to term the so-called physical phenomena, energetic.

That such a conception is possible is now generally acknowledged, but its utility is usually doubted. These doubts are at present justified, inasmuch as a complete exposition of the physical sciences from the point of view of energetics has not been thoroughly carried out. If the above-mentioned criterion of a scientific system, *viz.*, the conformity of the representing manifoldness to the one depicted, be applied to this question, we shall find unmistakably that all previous systematizations, which in the form of hypotheses have been attempted in these sciences, are faulty in this respect. Hitherto manifoldnesses have been used for the purpose of 'depicting' experiences the character of which corresponded to the depicted object only in a few main points. No attention was paid to the necessity of exact correspondence. There was no concise formulation or investigation of this side of the problem.

Now the energetic point of view permits as great a certainty in the method of depiction or expression as is necessary or possible for the state of the science at the time. For the manifoldness-character of each department there is a special form of energy. Thus science has long since distinguished between mechanical, electrical, thermal, chemical and other forms of energy. All these different varieties are related through the law of transformation with the conservation of energy. They are therefore organically connected. On the other hand, it has been possible to find the energetic expression for every manifoldness as yet discovered empirically. The future system of energetics in its entirety will therefore be a table of all the possible manifoldnesses of which energy is capable. It must be noted, however, that as a consequence of the law of the conservation of energy, energy is of necessity a positive magnitude which furthermore is without limit additive. Each special kind of energy must therefore also have this character.

The very slight degree of manifoldness which these conditions seem to leave us is increased very much by the fact that every form of energy may be resolved into two factors. The latter are subject to but a single limitation, *viz.*, that their product, energy, fulfils the above conditions, while they themselves are far more free. Thus, one of the factors of a form of energy may become negative instead of positive, if the other factor also becomes negative.

Accordingly it would seem possible to construct a table of all the possible forms of energy by assigning to the factors of energy all possible manifoldness characteristics and combining them in pairs, with the subsequent elimination of the products which do not conform to the conditions stated on p. 234. By comparison with all the forms of energy known at the time, it would be possible to discover the forms that were still unknown and to outline their most important properties. Experience would merely have to discover their specific constants. For some years I have myself from time to time attempted to carry out this program; but hitherto I have not progressed far enough to justify the publication of the results already obtained.

If now we turn to the biological sciences, the new phenomenon we meet is *life*. If we limit ourselves to observable facts excluding all hypotheses, we shall recognize as the universal characteristic of all life-phenomena the stationary stream of energy which flows through a comparatively constant structure. Metabolism is merely a part, though a most important part, of this stream. Plants, particularly, demonstrate immediately the paramount importance of energy in its most immaterial form, the sunbeams. Self-maintenance and repair with the production of similar descendants are other essential characteristics. All these characteristics must be present in order that an organism may arise. Furthermore they must be present if the knowing individual is to be capable of forming, by repeated experiences, a concept of any given organism, say a lion or a mold. Other organisms not fulfilling these conditions may occur. Because they are unique, they do not lead to the concept of a species, but are excluded (except of course for special purposes) from scientific consideration as 'malformations' or 'monsters.'

Whereas organisms mostly deal with forms of energy which are familiar to us in the inorganic world, we find the higher forms possessed of organs which undoubtedly produce, or are active in, the transformation of energy, though we do not know which form of energy acts within them. These organs are termed nerves; and their functioning is regularly of such a nature that upon the application of a definite form of energy to one end, they call into action at the other end forms of energy there present and which there act in their own peculiarly characteristic way. That energetic changes do occur in the process of nerve-transmission may be regarded as settled. We are therefore justified in speaking of nerve energy, leaving the question open as to whether it be a special form of energy or merely chemical energy or lastly a combination of several forms of energy.

While these processes of nerve stimulation with corresponding reaction in the end-organ, a muscle, for example, may be observed objectively, we find within ourselves connected with this nervous process

a new kind of phenomenon which we term self-consciousness. From the correspondence of our reactions with those of other people we conclude with scientific probability that they too are possessed of self-consciousness. We draw the same conclusion concerning a few of the higher animals. How far down the scale anything similar is present is not to be ascertained with the means at our command to-day, for the analogy between organization and action rapidly diminishes as we pass down the scale. Still in view of the very great gulf between man and the higher animals, this series is presumably not very long. Moreover, there are many reasons for regarding the gray cortical substance of the brain with its characteristic pyramidal cells as the anatomical substratum for this kind of nervous activity.

The study of the processes of self-consciousness is the subject-matter of psychology. Some departments usually considered a part of philosophy really belong to this science, *viz.*, the theory of knowledge. Esthetics, and still more ethics, are, however, a part of social science.

The latter deals with beings in so far as they may be combined in groups with common functions. In place of an individual mind we have here a collective one. The latter, by virtue of the average struck between the variations of the individuals, presents simpler relations than the former. Thence we may deduce the problem of the historical sciences. The events of our world depend partly upon physical, partly upon psychological factors. Both show a one-sidedness in regard to time. Thus arises, on the one hand, a history of the sky and the earth; and, on the other, a history of the organisms up to man.

The problem of history is to fix past facts through the effects they have wrought. Where the latter are not present we are dependent for a conception of the facts upon that most uncertain procedure, analogy. We must observe, however, that an event which has left no trail has absolutely no interest for us. Our interest in an event is directly proportional to the extent of the change it has produced upon the present. The problem of history is, however, as little exhausted by determining past facts as is that of physics by ascertaining an isolated fact, such as determining the temperature of a given place at a given time. The individual facts serve rather to discover the general properties of the collective mind; and the much-discussed laws of history are laws of collective psychology. Just as physical and chemical laws are discovered in order that with their help we may predict future events (such as those produced in experiment or technology), so laws of history should render possible the control and the development of society and of politics. We observe that the great statesmen of all times assiduously studied history; and hence we may conclude that, despite the doubts expressed by many scholars, numerous laws actually exist in history.

If after this cursory survey we review the ground we have covered, we shall recognize the following general relations: In each case the development of a science consists in correlating concepts formed from definite abstractions derived from experience; and by this means we achieve in our minds a mastery over certain parts of our experiences. Such correlations are termed according to the degree of their universality and reliability, rules or laws. A law is the more important, the more definite its statement concerning the greatest possible number of things; and the more accurately it consequently permits of predicting the future. Every law is based upon incomplete induction and is therefore liable to modification by experience. Hence the development of science is of necessity twofold.

In the first place actual relations are examined to see whether or not new relations other than those already known may not be discovered, *i. e.*, constant relations between individual peculiarities. This is the inductive method. And because the possibilities of experience are unlimited it must ever be an incomplete method.

In the second place, relations discovered by induction are applied to cases which have not yet been investigated. Cases resulting from the combination of several inductive laws are particularly liable to be studied. If the combination is correctly made and if the inductive laws are absolutely certain, the result has a claim to unconditional validity. This is the limiting case which all sciences strive to approach. It is almost attained by the simplest sciences, mathematics and certain parts of mechanics. This is termed the deductive method.

In the actual practise of every science both methods of investigation constantly alternate. The best method to discover new and significant inductions is to make a deduction even though its basis be insufficient, requiring subsequent proof from experience. Sometimes the investigator is not conscious of the separate steps of his deduction. In such cases scientific instinct is spoken of. On the other hand, great mathematicians have informed us that they used to find their general laws by induction, by trying and considering individual cases, and that their deductive derivation from other known laws is an independent operation which at times did not follow until much later. Even today there are a number of mathematical propositions which have not reached the second stage and which are therefore at present of a purely inductive and empirical character. The part that such laws play in the sciences rapidly increases as we pass up the series.

Another peculiarity which may be mentioned here is that in the series all preceding sciences assume the characteristics of applied sciences in respect to succeeding ones because they are essential to the course of the last without being themselves increased. They are merely helps to the latter.

If, in conclusion, we ask what influence investigations such as have just been sketched in outline can have upon the development of the future the following may be said: Whether a great and influential man of science develop and where, has hitherto been regarded as an event quite beyond control. All are agreed that such a one is one of the most precious treasures a nation (or indeed mankind) may possess. The conscious and regular training of such rarities had not been considered possible. While this is still true in the case of the quite exceptional genius, nevertheless countries of old civilization, at present notably Germany, exhibit an educational system at their universities which yields a regular harvest of young men of science, masters not merely of existing knowledge, but also of the technique of discovery. In this fashion the growth of science has been rendered sure and regular while its practise has been raised to a higher plane. These results have hitherto been attained by essentially empirical or even accidental means. It is the problem of the philosophy of science to regulate and systematize this activity in order that success may no longer depend solely upon individual talent, but may also be achieved by less original minds. Mastery of method, moreover, leads the exceptionally gifted individual to considerably higher achievements than he could attain without it.

THE JEWSHARP

BY THE LATE DR. H. CARRINGTON BOLTON

THE common English name of this primitive musical instrument is misleading, for it is not a harp nor has it any associations with Hebrews, as its appellation seems to imply. That it has nothing to do with Jews as respects either its origin or its employment is easier to demonstrate than it is to determine the real significance of its name, or the occasion of its invention. Antiquarians and lexicographers have attempted to trace the history and etymology of this term, but their suggestions are for the most part mere guesses.

Samuel Pegge, an antiquary of the eighteenth century, derives jewsharp from 'jaw's harp,' which is regarded by later authorities as absurd; and Skeat in his useful 'Etymological Dictionary' takes the singular view that this name was 'given in derision, probably with reference to the harp of David.' Dr. Littleton, adopting the vulgar error that the instrument is Jewish, inserted in his Latin Dictionary (1679), the phrase 'Sistrum Judaicum,' a mere translation, notwithstanding the fact that the term *Crembalum* had been used sixty years before by Praetorius in his 'Organographia.' After all, the simple proposition of another writer is not so improbable as it might seem; he suggests that, after a long interval of disuse and of forgotten name, the instrument was peddled through England and Scotland by a Jew, and the name jewsharp became naturally the popular one.

Another distinctive name current prior to the nineteenth century was 'trump,' or 'jews' trump,' prevalent especially in Scotland. The earliest mention of this musical instrument known to the writer has the latter form; in Sir Richard Holland's 'Duke of Howlat,' a Scottish poem satirizing King James, occurs a long list of musical instruments, from which we take a single line:

> The trump, and the talburn, the tympane but tray.
> (Line 760.)

This poem dates from the middle of the fifteenth century. The word trump is almost identical with the French 'trompe' applied to the jewsharp, as well as to several other musical instruments, the trumpet, the horn and even the rattle. Another common name in French is 'guimbarde'; in German the term is 'Maultrommel,' and 'Brummeisen'; in Italian it is known by the poetical expression, 'Scaccia pensieri,' banisher of thought. The word trump prevailed in Scotland, as was natural, considering the intimacy with France, and the phrase jews' trump was used by English dramatists until the end of the seventeenth century. Henrie Chettle, in the poem 'Kind Hearts' Dream,' dated 1592, wrote: "There is another juggler that being well skilled

in the Jews' Trump takes upon him to be dealer in musick." In the following century Thomas Randolph wrote:

> O, let me hear some silent song
> Tun'd by the Jews' trump of they tongue.
> (The Conceited Peddler.)

About fifty years later Thomas Otway in his 'Friendship in Fashion' represents one of the actors, 'Malagene,' pulling out a Jews' trump and playing a tune. (1685.) Some wiseacre, seeking the derivation of Jews' trump, makes the suggestion that it is a corruption of *jeu-de-trompe,* but the guess loses much force owing to the simple fact that this expression does not occur in French.

In 'Hakluyt's Voyages'[1] the instrument is called simply 'Jewes-harpe.' The early explorers found these toys very advantageous as articles for trading with the aborigines; the barter of 'hatchets, knives and jews-harps' is mentioned by R. Duddeley, in 1595, and one year later Sir Walter Raleigh wrote of the same people: 'Wee should send them Jewes-Harpes, for they would give for every one two Hennes.'

These baubles were also acceptable to the natives of Guiana in South America; R. Harcourt names them in connection with beads and knives. This trade with the aborigines of the western continent has continued until modern times; Mr. Joseph D. McGuire refers to it in connection with his description of a pipe of catlinite carved in form of a jewsharp.[2]

In Bailey's Dictionary, which dates from the eighteenth century, the term is jewstrump, and in Teesdale's 'Glossary' still another synonym is used, 'gew-gaw'; this last name is also used for a kind of flute in Scotland.

This humble instrument of music, treasured chiefly by semi-civilized races and by children of intellectual nations, is but rarely mentioned in print, as its mediocre qualities give it no prominence in musical circles, and toys are seldom subjects of discussion. Sir Thomas Brown states that a brass jewsharp richly gilded was found in an ancient Norwegian urn; this suggests great antiquity, a point which will be discussed later.

In the report of those horrible witch trials conducted in the reign of James VI. of Scotland, in 1591, the 'grave and matron-like' Agnes Sampson and the poor servant Gellie Duncan play conspicuous and melancholy parts. After horrible tortures, Agnes confessed that Gellie, Dr. Fian and herself, with upwards of two hundred witches, used to assemble at midnight in a kirk, where they were joined by the devil himself, who incited them to murder the king. On these occasions the devil always liked to have a little music, and Gellie Duncan used to play a reel on a trump, or jewsharp, while all the witches danced. And at another time when a large number of witches marched in procession

[1] 'Hakluyt's Voyages,' III., 576.
[2] Report National Museum, 1897, p. 488.

to hear the devil a-preaching, Gellie Duncan, the musician of the party, tripped on before, playing on her jewsharp and singing:

> Cummer, go ye before, cummer go ye;
> Gif ye will not go before, cummer, let me.

The Skene manuscript of Scottish melodies, written about the years 1615 to 1620, mentions the trump, and William Daunay commenting on this says the jewsharp was the only instrument of music formerly known to the inhabitants of St. Kilda; and as this isolated, rocky island had only twenty-seven families residing there in 1793, Daunay's statement seems credible.

These few notes and the references scattered through that rich treasury for antiquarians, the English 'Notes and Queries,' are evidently written by persons ignorant of the birthplace and great antiquity of the jewsharp; examination of the collection in the U. S. National Museum, however, shows that Asia can indubitably claim that distinction, for the primitive models preserved there prove that these musical instruments are widely known throughout the Orient. They are common in the Chinese empire, Thibet, Burmah, Siam, and Japan, as well as in the islands of Borneo, New Guinea, Sumatra, Samoa, Fiji and the Philippines. The Chinese call the jewsharp *Keou Kin*, 'mouth harp,' and consider it very ancient, and with some reason, for it is found among the Ainos, the original inhabitants of Japan, of whom a few survive in the northern islands.

As constructed by orientals who have not been influenced by contact with Europeans and Americans, their jewsharps are made of narrow pieces of bamboo from five to nine inches in length, and split so as to form a longitudinal section in which the jaws and tongue are cut somewhat like a three-pronged fork. A portion of the bamboo, of full size, is sometimes left attached to the split section to serve as a handle, and this measures in addition five to seven inches in length.

Often the construction is peculiar in that the jaws of the instrument are made to vibrate instead of the tongue, in which case the tongue occupies an inverse position. In jewsharps made by the Ainos the vibration of the tongue is effected by a bit of bamboo fiber fastened to a minute orifice at its base. These wooden jewsharps have little power, and the modern Chinese, imitating Europeans, make them of iron with a projecting handle, which is virtually a prolongation of the tongue beyond the point where it is riveted to the jaws.

Several native tribes in the Philippines make jewsharps—the Moros, on northern Mindanao, the inhabitants of the Sooloo archipelago and the Negritos. In Burmah and Thibet, where the common name is Murchang (or simply Chang), they are not made by the Thibetans themselves, but by the Lissus and by tribes in the southeastern districts, where nearly all women carry jewsharps in ornamental cases suspended

from their girdles. Melodies are played on three having a different pitch.

For the opportunity of examining the collection in the National Museum and information concerning them I am indebted to Professor Otis T. Mason, acting curator in anthropology, and to Mr. E. H. Hawley, preparator in charge of musical instruments.

The Waschamba tribe in Africa make a childish toy used like a jewsharp, quite unique in construction. Near the end of a pith-bearing stem is cut a small orifice communicating with the central bore, and a thin section of the outer bark or rind of the stem is split so as to form the tongue; this is vibrated by gently striking it with a strip of wood, at the same time that air is blown into the tube through the small orifice. The character of the sounds obtained is not given by the ethnologist who describes this primitive instrument.[3]

In occidental countries jewsharps are manufactured on a large scale; they were manufactured in Nuremberg as early as 1524. In Birmingham one dealer, who made thousands of gross in 1895, packed them in boxes labeled 'Irish Harps,' a better designation for trade.

Regarded as an instrument with musical capabilities, the jewsharp was studied by the distinguished English scientist Sir Chas. Wheatstone in 1828. He wrote as follows:

> The jewsharp consists of an elastic steel tongue riveted at one end to a frame of brass or iron (shaped like a horseshoe). The free extremity of the tongue is bent outwards to a right angle, so as to allow the finger easily to strike it when the instrument is placed to the mouth and firmly supported by the pressure of the parallel extremities of the frame against the teeth. The vibrations of the tongue itself correspond with a very low sound, but being placed before the cavity of the mouth, the form and dimensions of which are capable of various alterations by the motions of the tongue and lips, when the number of vibrations of the contained volume of air is any multiple of the original vibrations of the (steel) tongue, a sound is produced corresponding to the modification of the oral cavity.

After specifying the notes yielded by a given instrument, he continued:

> This scale of notes is too incomplete and too defective to allow even the most simple melodies to be played on a single jewsharp, but the deficiencies may be supplied by employing two or more of these instruments.

And he refers to a celebrated performer, Mr. Eulenstein, of whom more anon.

The mouth forms a resonant cavity or sounding box, analogous to the body of a guitar, or to the stretched parchment of a banjo, the pitch varying with the form and size of the cavity; every one has noticed that in pronouncing the vowels *a, e, i, o, u* in their natural order the cubical capacity of the mouth is gradually diminished.

A few persons have acquired such proficiency in playing the jewsharp as to gain recognition in history and literature. Koch, a private in the Prussian army under Frederick the Great, played with extraor-

[3] Bernhard Ankermann, 'Die Africanischen Musik-Instrumenten,' inaugural dissertation, p. 47, Leipzig [Berlin, 1902].

dinary skill, and of him the following story is told. One summer evening, sitting by an open window, the king overheard strains of music of unusual quality, and on making enquiry learned that they arose from a jewsharp played by a soldier doing sentinel duty in the garden. Thereupon Frederick commanded the musician to ascend to his suite of apartments and to play before him, but young Koch politely refused to do so without an order from his colonel. 'But I am king,' said Frederick. 'I know it, your majesty, but I can not leave my post, or I shall be punished.' Although very angry, the king respected the sentinel's candor and fidelity. On the following day Koch, by invitation of the king and an order from the colonel, played in Frederick's apartments and so delighted him that the king gave him a sum of money and an honorable discharge from the army. Koch then traveled through Germany, giving exhibitions of his skill and playing in concerts, whereby he accumulated a moderate fortune. The chief attraction of Koch's playing was his descriptive music, pieces similar to the 'Turkish Patrol'; he used to depict a funeral procession marching along to the tolling of bells, the approach and passing of a chorus of mourners, and their singing of an old German popular dirge.

In the first decade of the century just closed Heinrich Scheibler, of Crefeld, invented an instrument which he called 'Aura'; it consisted of ten jewsharps of different keys grouped in two series of five each and fastened to a disk, with the bows towards the center, so that the jaws diverged like rays. With this combination he performed in concerts before large audiences, producing surprising and beautiful effects.

But by far the most eminent performer on jewsharps was a man named Charles Eulenstein, born in Würtemberg about 1802. He spent many years studying the capabilities of the jewsharp, and being an accomplished musician, he found that the best effects could only be obtained with instruments of different pitch, and he had manufactured sixteen jewsharps, on four of which he was able to play at once by connecting them with silken cords so arranged that he could grasp four with his lips. He appeared in London in 1827–8 and had great success playing in concerts and producing effects greatly admired by amateurs. Eventually his teeth were injured and he had them repaired by a clever dentist, who coated them with some glutinous substance that aided him in supporting the iron instrument. He also performed in Scotland and on the Continent; he was still living in 1878 at Ulm.

Wheatstone wrote of this expert as follows:

> Mr. Eulenstein by using sixteen jewsharps was able to produce effects truly original and of extreme beauty. Those who have heard only the rude twanging to which the performance of this instrument in ordinary hands is confined can have no idea of the melodious sounds which in Mr. Eulenstein's hands it is capable of producing.

GEOLOGICAL HISTORY OF COCKROACHES

By Dr. E. H. SELLARDS,
UNIVERSITY OF FLORIDA

NO insects are more abundant as fossils, and none so widely distributed through the various formations, as are the cockroaches. Their delight in moist places, often near the banks of streams, their firmly chitinized wings and body render them of insects among the best adapted for preservation. Especially are they to be expected in association with ferns and other plants among which during life they found shelter, and together with which they were transported to their resting place in the rocks. Hardly ever will persistent search among fossil leaves of land origin, when imbedded in rocks of sufficiently fine texture, fail to bring to light at least detached wings and perhaps bodies. Even when the bodies of adults have not been preserved, not infrequently will be found the cast-off integument of the young. It is this approximately complete geological record that lends an especial interest to the cockroach family.

The cockroaches have proved themselves a remarkably conservative group having retained throughout their long existence, as compared with other insects, a relatively generalized structure. The development is direct, the young resembling the adults. The mouth parts are of the biting kind common to primitive insects. The segmentation of the abdomen and thorax is distinct. The foot is five-jointed. The venation of the wing is much less complicated than that of many of the more advanced types. Not all the organs, however, have retained this primitive simplicity. In this, as indeed in every group, some organs have outrun others in degree of specialization, so that the group early became a characteristic and well delimited one. The body is flattened, the head small and turned downwards. The covering of the first thoracic segment, the pronotum, is enlarged, rounded, more or less shield-shaped. The front wing is firmly chitinized and lies flat on the back, or slightly arched to conform to the shape of the thorax. An inner area near the base of the wing is marked off by a deep curved line, the anal furrow. The hind wing is less resistant and broader, the greater width being obtained by a greater expansion of the inner border. Hardly ever will a doubt arise as to the reference to this family of even a fragment of a specimen.

The structural characters so far mentioned made their appearance early. The rounded pronotum is as characteristic of Paleozoic as of

recent cockroaches. The thick arched front wing with strongly delimited anal area dates from the Carboniferous. The group, however, has by no means remained stationary since the Carboniferous. On the contrary, close observation reveals evidence of advance along distinct and definite lines. The Carboniferous cockroaches are provided with a long ovipositor resembling that of the katydids or crickets; modern cockroaches have a reduced and specialized ovipositor. Early cockroaches no doubt deposited their eggs in the ground or under the bark of trees or within the tissue of succulent stems; modern forms deposit their eggs in a very characteristic egg case. The front wings

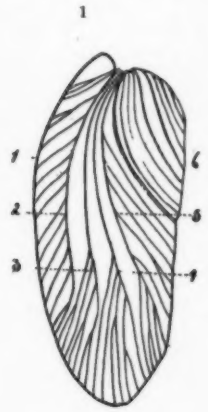

FIG. 1. Front wing of a typical Coal Measure cockroach, *Gerablattina arcuata* Sellards. 1, costa; 2, sub costa; 3, radius; 4, media; 5, cubitus; 6, anal veins. Twice natural size. Author's illustration.

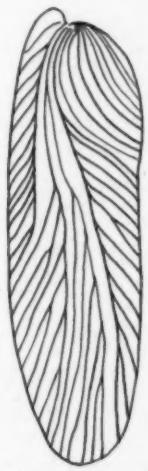

FIG. 2. Front wing of a Permian cockroach, ×5. Original drawing. Gn. sp. new. Author's Mns.

FIG. 3. Front wing of a modern cockroach, *Ectobia germanica*, × 5. Original drawing.

From a comparison of the three types, Carboniferous (oldest), Permian (later), and (Fig. 3) modern, it is seen that: the wing has become increasingly slender and compact; the main veins have become partly fused; cross veins have developed, and the direction of the anal veins has changed.

have become in general more resistant, the venation more complicated. The hind wings have developed plications and a longitudinal fold. The value to biology of a study of the group is in direct proportion to the completeness with which these changes and the laws governing them can be traced out.

The wing of a typical cockroach of Carboniferous time is of simple structure. A border vein, the costa, traverses and strengthens the costal border. Four strong veins arising close together near the base of the wing diverge and supply the greater part of the wing membrane. The first of these, the subcosta, meets the costal border about or beyond the middle length of the wing; numerous superior branches are

given off which strengthen the upper edge of the wing. The following vein, the radius, reaches as a rule to the apex, and its branches given off from the upper side fill the apex. The medius, which is often of lesser importance, terminates on the inner border not far from the apex, and gives off a few usually superior branches. The fifth vein of the wing, the cubitus, is of more importance. It reaches along the inner border of the wing one half to two thirds the distance towards the apex, giving off strong inferior branches which strengthen the lower edge of the wing. The remaining small area on the lower inner corner of the wing is marked off by a deep furrow. The veins of this area are all simple or once forked, and pass with a uniform curve from their origin to the inner border.

The next type (Fig. 2) is from later deposits—the Permian. Here two of the main veins, the radius and media, have become fused for a little distance from their origin, so that instead of four strong veins arising from the middle of the base there are here only three. Otherwise the wing is not unlike the Coal Measure form. Many of the mesozoic wings have, in addition to a partial fusion of two or more of the main veins, a further radical change in the anal area, the veins of which, instead of ending on the inner border, run to and end on the anal furrow. The front wing of one of the living cockroaches, the common 'croton bug,' is shown in figure 3. Here cross veins are numerous, and the anal veins, as in most of the Mesozoic forms, end on the anal furrow. The wings described are those which are in a general way typical of their time. Along with each of these are found wings, some of which are more advanced, while others are of more simple structure than those illustrated. Among modern cockroaches not a few genera and species have both front and hind wings so incompletely developed as to be entirely useless, and present only as functionless wing pads. All Paleozoic cockroaches, so far as known, were provided with fully developed functional wings, the modern wingless forms having descended without doubt from winged ancestors.

The hind wings of Carboniferous cockroaches are as a rule broad with rounded inner border; the veins are evenly distributed; there are no cross veins; no indication of any fan-like plaiting such as is found in the hind wings of modern forms; apparently there was no folding, the wing lying spread out across the abdomen. Neither is there any differentiation into a thicker, brownish, outer part, and a thinner, membranous folded part. The hind wing, being less firm than the front, is naturally less often preserved. Nevertheless a considerable number have now been obtained. In the structure of the hind wing the Carboniferous cockroaches present fairly uniform characters, only occasionally, and from late Carboniferous deposits, are there indications that a folding of the wing had originated.

Some of the cockroaches of Permian time, however, had folded and plicated hind wings. A not uncommon type from the Kansas Permian is that shown in figure 5. This wing has a fold running through the anal area at (*b*), on one side of which the veins are longitudinal, while, on the other, they run down towards and end on the line of the fold. The wing in the specimen here illustrated is spread out full width. With other specimens, however, it is seen folded in the resting position, the veins of the two parts showing plainly through the thin membrane. Cross veins in the cockroach hind wing are here seen for the first time. A beginning of plication is also evident in the area between (*a*) and (*b*), while between the veins are developing accessory longitudinal veins necessary to support such plications. This wing also gives additional evidence of what had been previously demonstrated—plications, although now common to the hind wings of Orthoptera in general, nevertheless originated independently in several families of the order after they had diverged as distinct lines from the main stock. A similar need among the several families is here met by the development in each of a similar mechanism.

The hind wing of modern cockroaches presents a further development of the structures originating with these early ancestors. The hind wing is made to fit nicely under the front by a longitudinal fold. The wing is strengthened by numerous cross veins, and the anal area is very perfectly plicated. An increased expanse of the anal area is accompanied by a relative reduction in the other areas of the wing, especially the cubital. The folded area has remained flexible, while the more exposed part of the wing has become thicker, more resistant, and brownish in color.

This progressive change in the wing structure is accompanied by the reduction of the ovipositor from the long sword-shaped organ of the Carboniferous cockroach to the specialized organ of recent forms adapted to the purpose of holding and guiding the eggs into the egg case. Other organs of the body, if closely followed, would, doubtless, give evidence of similar progressive change. The organs described are those most readily preserved, hence best known in the fossil condition.

The young of any group of organisms are always of interest. A considerable number of young cockroaches have been found in the fossil condition, occurring often in deposits where the bodies of adults are rarely or never seen. In most cases the parts preserved are not the bodies of the young, but the cast off integument shed by the young cockroach with each successive molt. The body is heavy and transported with difficulty, the soft tissue hastens its decay, or more probably it is gathered up as food by the horde of hungry animals in the water or on land. It is not so with the molt, for it is useless as food, and like the detached wings with which it is always associated, is light

and easily floated by rains into streams and rivers, and thence carried by currents into larger bodies of water, where permanent deposits are accumulating. Both wings and molts are fairly resistant to decay, and thus more readily preserved than are the softer parts of the body. Such molts have been found in this country from the Coal Measures at Mazon Creek, Illinois; from the Upper Coal Measures of Eastern

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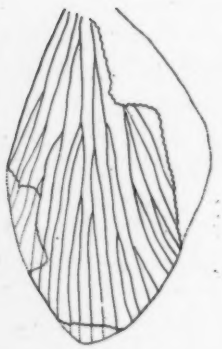

FIG. 4. Hind wing of Carboniferous cockroach, *Promylacris rigida* Scudder. Twice natural size. Author's illustration.

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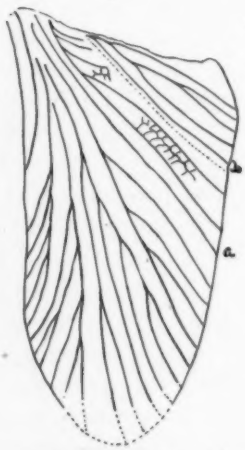

FIG. 5. Hind wing of a Permian cockroach, × 4. Original drawing.

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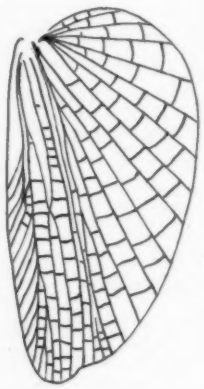

FIG. 6. Hind wing of a modern cockroach, *Ectobia germanica*. Original drawing.

The conspicuous changes in the hind wing as seen here are increased expanse of the anal area, increased proportionate breadth of the wing, origin and development of a longitudinal fold, development of plications in the folded area of the wing, development of cross veins.

Kansas; and from the Permian of Central Kansas. Recently an interesting specimen, shown in the accompanying illustration, has come to light from the Coal Measures of Clinton, Missouri.[1] A few specimens have also been obtained from the coal formation of Scotland. The young of Paleozoic cockroaches closely resemble the adults, and were evidently in form and habits very similar to young cockroaches of the present day.

The cockroaches of Carboniferous time are, on a general average, larger than those of later time. The largest described form, *Archoblattina Beecheri* Sellards, has a body, exclusive of the head, three and one half inches long, with an expanse of wings of six and one fourth inches. The Permian forms, and, also, those from mesozoic and later formations, are, so far as known, smaller than those of the Carboniferous.

There appears to be no authentic record of the occurrence of cock-

[1] Collected by Dr. J. H. Britts and transmitted by him to the National Museum. Kindly submitted to the writer for illustration by Dr. David White.

roaches in any rocks older than the Carboniferous. The single specimen reported from the Silurian of France is at best very unlike a cockroach. Its claim to affinity with the cockroach group was long ago contested by Scudder, and even Brongniart, its discoverer, has since conceded that it can not belong here. Other writers exclude the fossil entirely from the class Insecta. The oldest known species appear to be *Archimylacris parallela* Scudder and *Geroblattina fascigera* Scudder, from the Millstone Grit, or Middle Carboniferous. During Coal Measure time cockroaches became extremely abundant, more so than in any later period. They are less numerous in Middle and Upper Permian as well as in Mesozoic and later deposits. Nothing whatever is known of the insect life of the southern hemisphere during either Paleozoic or Mesozoic, and it yet remains to be seen what forms will be brought to light from this part of the world. During the Carboniferous and Permian, cockroaches were widely distributed over Europe and North America. With the uniform climatic conditions of that time it can hardly be doubted that their distribution was as wide at least as that of the tropical plants with which they are so constantly associated.

FIG. 7. Young of a Coal Measure cockroach, × 4. Original drawing.

FIG. 8. Natural size restoration of a typical Coal Measure cockroach, *Etoblattina mazona*. The protruding ovipositor and simple wing venation distinguish Coal Measure from modern cockroaches. Author's illustration.

Among the laws of development operative in bringing about the changes which have occurred in the cockroach family during its long geological history, those the effects of which are most apparent may be summarized under the following headings:

Recapitulation of Ancestral Characters.—During the nymph stages of a modern cockroach the venation of the immature wing is not unlike that of the typical Coal Measure adult. The main veins of the wing, which during these early stages are free to the base, later become more or less fused and cross veins appear, thus illustrating the law common to most groups of organisms and known as a recapitulation of ancestral characters.

Parallel Evolution.—A similar need among the several related families of the order Orthoptera to which the cockroaches belong has been met by the development of identical structures. Thus both the plications and the fold of the hind wings originated independently in the cockroach and some other families of the order.

Mechanical Principle.—Both the plications and the longitudinal fold of the Orthoptera wing seem to have been developed in response to the mechanical need of some means of caring for the largely expanded inner area of these wings.

Specialization by Reduction.—The reduction of the long ovipositor of early cockroaches to the short specialized ovipositor of modern forms is apparently an illustration of the law of specialization by reduction.

Loss of Organs Through Disuse.—The reduction of the wings of several modern species to such an extent that, although presenting normal adult features of venation and articulation to the body, they are so far vestigial as to be practically functionless, is doubtless to be attributed largely to lack of use, and results from the ground habits of these insects in which they use the wings comparatively little. Not infrequently functional wings are retained by the males, even when lost by the probably less active females of the same species.

Arrestation of Development.—The wings of not a few modern forms remain as nothing more than wing-pads similar to the wing-pads of the larval stages. This further reduction is probably an instance of what has been called arrestation. Although other organs of the body have reached maturity, the wings, checked in their development, have not passed beyond the larval stages. Lack of use of the wings by the ancestors of the species, and consequent insufficient blood and food supply to this part of the body, is probably in this case an indirect cause of arrestation.

HOW ROOTING AQUATIC PLANTS INFLUENCE THE NUTRITION OF THE FOOD FISHES OF OUR GREAT LAKES

By Professor RAYMOND H. POND

NORTHWESTERN UNIVERSITY

A THOROUGH investigation of the biology of our great lakes is in itself a desideratum worthy the expense. From the purely economic standpoint, however, our Bureau of Fisheries has long recognized the necessity of knowing more of those conditions under which products worth millions annually are produced. Until such an investigation has been made the natural factors which determine the quantity of food fishes these lakes can support must remain unknown.

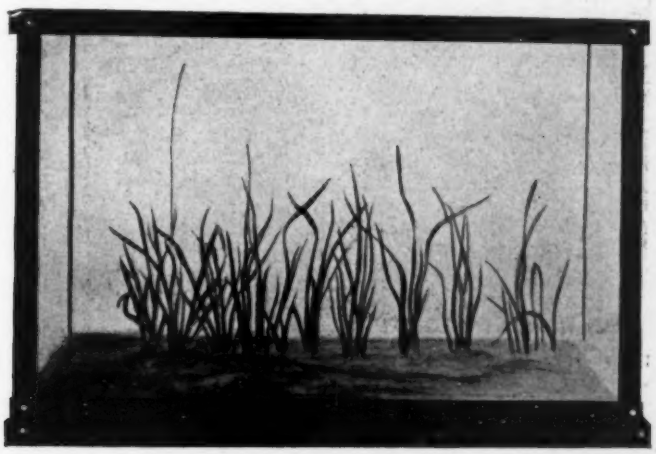

Fig. 1. *Vallisneria spiralis* after 7 weeks' growth rooted in lake soil. Plants in figures 1 and 2 originally the same size.

Fish, as all other living forms, reproduce in a geometrical ratio and, other conditions being favorable, will multiply up to the limit of their food supply. Thus it is that the problem of nutrition is very fundamental. To determine the source of nutrition of our fresh-water food fishes is in itself a considerable undertaking, but to ascertain what factors regulate the quantity of this nutrition is a colossal task.

The nutrient relations of aquatic life are perhaps no more complicated than those of terrestrial, but they certainly are more difficult to determine because of the numerous obstacles to observation and col-

lection of data. The higher orders of animal life are, of course, dependent upon the lower. The low free-swimming forms, called collectively zooplankton, are preyed upon by larger animals. The latter in turn are devoured by still larger forms and so on up to the fish. It is evident that all the animals above the zooplankton are dependent upon it, and whatever increases or decreases the quantity of zooplankton causes a fluctuation in the food supply of the fish. Thus it is that a quantitative study of the plankton forms so conspicuous a feature of the extended investigations which have been made both here and abroad of fresh-water biology.

Aquatic animals, just as terrestrial, are dependent upon plants for the organization of the elements of food into food. As there is an animal or zooplankton, just so there is a vegetable or phytoplankton. The latter is the living basis of the food supply of the aquatic fauna.

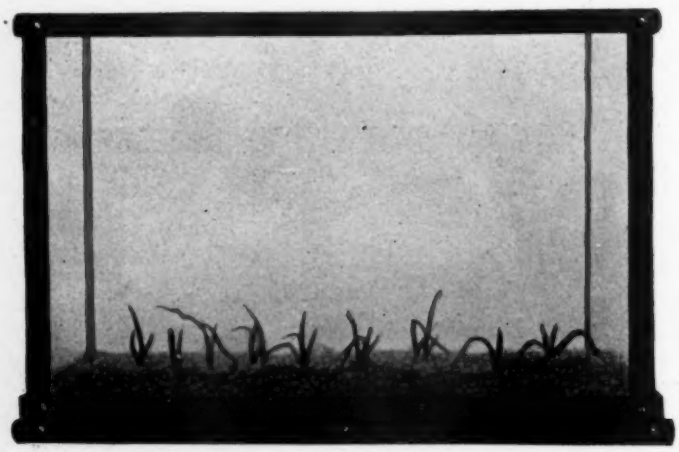

FIG. 2. *Vallisneria spiralis* after 7 weeks' growth rooted in gravel. Plants in figures 1 and 2 originally the same size.

This phytoplankton lives on substances which it makes for itself out of carbon dioxid and water and the mineral matter in solution in the water. The supply of water and carbon dioxid is, of course, unlimited. The supply of mineral food varies considerably in different bodies of water and in the same lake several factors may operate to cause a fluctuation. The rooting aquatic plants have long been suspected of being one of these factors, but whether they increase or decrease the mineral food has not until recently been known.[1]

The rooting aquatic plants may be considered in two groups according as they are submerged or emergent. The latter vegetation must,

[1] Pond, Raymond H., 'The Biological Relation of Aquatic Plants to the Substratum,' U. S. Fish Commission Report for 1903, 483–526, published 1905.

of course, take its nourishment from the soil. It has long been believed, and the statement is current in our latest and best text-books, that the submerged and rooting aquatics take their nourishment from the water which bathes them, that their roots are not for absorption, but merely for anchoring. An examination of the literature convinced me that so far as experimental evidence is concerned there is none which can be accepted as demonstrating this conclusion or a contrary one. The necessity of exact knowledge in this particular is apparent when we consider that if such plants, as hitherto supposed, feed from the water, they then during the entire growing season are diminishing the quantity of food for the phytoplankton. On the other hand, if

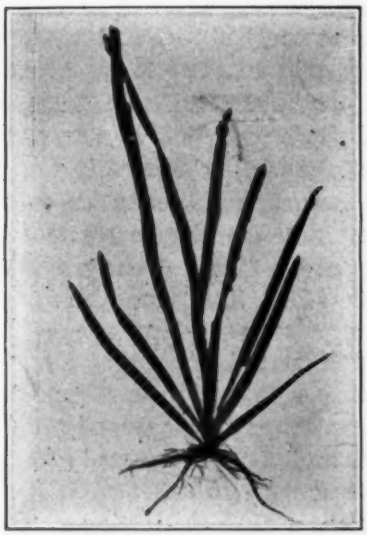

FIG. 3. *Vallisneria spiralis* after 5½ weeks' growth in loamy soil.

FIG. 4. *Vallisneria spiralis* after 5½ weeks' growth in sandy soil.

this food comes from the soil they not only do not reduce the plankton food supply, but actually become important contributors to it in that the mineral food taken by them from the soil finally through their decay becomes available to the phytoplankton. That the latter alternative is the true one may be seen from the following glimpse of an experimental study.

The special organs of absorption in terrestrial plants are the delicate root hairs which occur on the young roots in a narrow zone situated just back of the growing tip. The quantity of such hairs can, in the laboratory, be made to vary greatly by regulating conditions, showing that they are sensitive structures and not likely to be produced unless needed by the plant. Some land plants are known which do not have root hairs, but they are exceptions. On the other hand, aquatic plants

have been supposed to be without such hairs. Examination of specimens taken from the lake bottom very carefully revealed their presence, however, and aquarium cultures in the greenhouse show that, like those on land plants, they are sensitive to the conditions of their environment. The presence of such hairs is almost *prima facie* evidence that the organs bearing them have an absorptive function in addition to an anchoring one. This conclusion was tested in several ways. It was found that such plants could not make a normal growth unless rooted in favorable soil. Clean washed sand could not be substituted for good rich soil. Likewise a clay soil does not support a normal growth. Thus we find that these aquatics are quite sensitive to the nutritive quality of the substratum. In fact their existence depends upon this, as none of the larger plants growing submerged in western Lake Erie can mature a generation on the nourishment they are able to secure from the water alone. Chemical analysis shows that plants which have been denied soil nourishment are deficient in nitrogen, potash and phosphoric acid, as compared with others allowed to root in the soil.

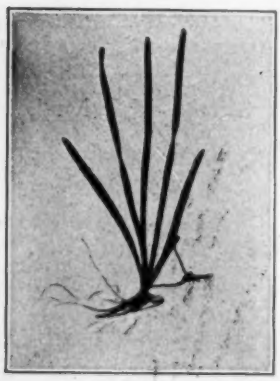

FIG. 5. *Vallisneria spiralis* after 5½ weeks' growth in clay soil.

Some plants are more dependent upon the soil than others, thus *Ranunculus aquatilis* made 63 per cent. better growth in soil than in clean washed sand. *Elodea canadensis* made 340 per cent. and *Potamogeton perfoliatus* 480 per cent. better growth in soil than in sand. Such results show clearly how important a place the rooting aquatics occupy in that chain of nutrient relations which stretches from the fish down through the orders of animal and plant life to the soil.

In the stocking of ponds for fish culture attention should be given to the plants allowed to grow. The species mentioned above are favorable, while *Ceratophyllum* is not. The latter plant often makes a very abundant growth. Though frequently accidentally anchored to the bottom, it does not bear roots and must, of course, take its nourishment from the water. A small lake in which this plant had made a very abundant growth was found by another investigator to have less plankton than other neighboring lakes in which the bulk of the vegetation was rooting.

URBAN AND RURAL LIFE

By FRANK T. CARLTON

At the beginning of the twentieth century, approximately one third of the total population of the United States were living in cities, and were classed as urban inhabitants. A considerable percentage of this twenty-five million human beings are to-day living in crowded and uncomfortable quarters, despite the evident fact that there exist in nearly all sections of the nation many valuable abandoned farms and half-deserted villages. The exigencies of manufacture and trade, and the glamor and hurry of city life, as contrasted with the dullness and monotony of rural existence, have gathered this great host of men, women and children into our crowded, smoky, restless cities. In the building of the modern manufacturing and commercial city, everything held dear by the poet and the lover of humanity has been ruthlessly and heedlessly sacrificed on the altar of industry and wealth. Human life and happiness have been overlooked or ignored in the mad scramble for wealth, trade and power. Exports and imports, bank clearances, cotton, sugar, oil, beef, iron and steel, not men, or women, or children, are the important and desirable, even the paramount, considerations. Human health and human weal are thrown in the balance against gold and silver, and are found wanting. The unparalleled growth of cities during recent decades is, in a large measure, to be attributed to modern methods of transportation of goods and people, and of transmission of energy and intelligence. Change the conditions in regard to any one of these items, and the forces which make for centralization or decentralization are modified or reversed. Railroads and electric wires, telephones and telegraph instruments, rural free delivery and good roads are important factors in the distribution of population.

Great populations have migrated from country to city; long-established modes of living are quickly changed; old customs and habits, upheld and cherished by the dearest traditions, are suddenly brushed aside. A race of city dwellers is being developed. On the very threshold of a new century these questions are forced upon a reluctant people: Can a nation grow strong, vigorous and progressive if a large percentage of its population are dwelling in cities? Is city life natural? Is the sharp demarcation between rural and urban conditions conducive to healthful political activity? Are decentralizing tendencies becoming noticeable?

History records many rhythmic movements in human society. Cer-

tain tendencies are developed and carried to an extreme; but sooner or later new forces appear which produce a reaction; and the pendulum swings backward. The flood tide of city migration is near; an ebb toward the rural districts may be anticipated. Indeed the stream of population flowing toward the cities is being, in a measure, diverted into suburban channels; and at the same time a counter current is setting in from the crowded tenement-ridden quarters toward the more healthful outskirts of the city, where grass and trees are not wholly unknown. Our modern cities, our great manufactories, our railroads and our enormous trade are the results of the extensive use of steam power. While factories and cities did exist before Watt made his famous invention, conditions were radically different from those of to-day. Steam has molded our present civilization. But in recent years a new distributor of power, electricity, has come into extensive use. As a result the economies and limitations which caused centralization and crowding during the century of steam are removed to some extent. Electricity is modifying the distribution of population.

The movement toward the suburbs can be noticed by even a casual observer. Manufactories and residences are being built in the suburbs. Factories and homes are no longer erected in close proximity to each other. Shops are now designed to occupy a larger ground area, and are located further from each other. The age of decentralization is just ahead; the suburb is absorbing more and more of our city population.

The suburban type is becoming characteristic; the commuter is a constantly increasing factor among our people. Improved methods of communication and of transportation, better roads, rural mail delivery and new methods of transmitting power are substituting decentralizing for centralizing forces. As the country is covered with a network of trolley and telephone wires, the area available for the residence of city workers is enlarged. The use of elevated roads, inside the city limits, for suburban electric lines will still further lengthen the radius of the circle. Country or suburban homes, equipped with many city conveniences and advantages, are now available for the man engaged in business in the city. Country life of the immediate future is not to be what it was in the 'good old times'; new forces and new influence are infusing new life into the rural communities. Rural isolation will soon be a thing of the past in nearly all sections of the eastern and north central states.

The American people are beginning to recognize vaguely that life in a crowded city is not the best and most wholesome for men and women. Many individuals are buying homes in the country for purely sentimental reasons. But behind this sentiment is an unerring instinct which leads us back to contact with the soil and to communion with

nature, to a simpler and less artificial kind of living; and also in the shadow of sentiment is an industrial situation which is steadily losing its antagonism to this instinct.

Furthermore, at the very moment when the forces of decentralization begin to make themselves manifest to the keen observer, a determined demand for governmental regulation of railroad rates appears. Railroads, as everybody understands, have played an important rôle in assisting the enormous growth of population at certain geographical points; they have undoubtedly wielded the power to build up towns and cities, or of retarding their development. Railroad companies have often exhibited a disposition to punish the small town, particularly if its location is such that there is little or no competition in regard to transportation. While electric lines offer indeed a partial remedy for this unfortunate situation, measures directly affecting the steam lines are needed, if this discrimination is to be entirely removed. If the United States government is in the future to take an active part in the control of railroads and the regulation of railroad rates, the people must decide whether centralizing or decentralizing forces shall be aided by the railroads, whether the large city shall be favored over the smaller one or the town, and whether the large shipper shall be permitted to receive special privileges in the shape of reduced rates on large or frequent shipments or for goods shipped under peculiar conditions, as, for example, in private cars. In the discussion of railroad-rate regulation the question of the treatment of small towns as compared with that accorded to cities ought not to be ignored. If railroad rates are to be determined or modified by governmental action with a view of benefiting the general public, we must decide whether the suburban type is desirable in the immediate future. We must, knowingly or unknowingly, stand for or against centralization of population and manufacture. Shall we use the power to regulate freight and passenger rates so as to accelerate or retard the growth of the suburbs? What is to be our attitude on this question? Shall we use the forces of legislation so as to act with or contrary to those economic and physical forces which are building up the suburbs, and which work unceasingly to mold our civilization into the suburban type?

As mankind becomes more highly civilized, wants become more numerous and varied. In a century, the civilized world has been advanced from a condition of penury to one of plenty; life is now more complex. The luxury of yesterday is the simple life of to-day. Requisitions for food, clothing and shelter are supplemented by demands for intellectual, social and esthetic enjoyment. Since machine production is employed chiefly in satisfying the demand for the common necessities of life, and because skilled and artistic work is necessary to create those articles and to furnish the services which partic-

ularly appeal to the artistic and esthetic demands of man, as wants of this latter sort develop, skilled workers will be gradually transferred from one class of industry to the other. Successful skilled workmen require clean, commodious and healthy home and shop environment. A demand for skilled craftsmen points toward a revival of village industry; because in the village or the suburbs only, as a rule, can such an environment be found at an expense which is not prohibitive. The use of water power and electrical transmission is especially suitable for furnishing power to small establishments. An authority on this subject has recently stated that about four fifths of the total water-power of the United States is found in falls furnishing less than one thousand horse-power; and that many now unutilized falls may be acquired and equipped to furnish electrical energy at a very reasonable cost per horse-power developed. The economic and industrial advantages are not all monopolized by the large business; but governmental regulation of railroads and of the exploitation of natural resources can also do much toward giving the small fellow and the small municipality a 'square deal.'

The steady increasing attention granted to art, architecture and the crafts movement, and the growing demand for public parks and playgrounds, are not entirely disconnected or distinct from the movement toward the suburbs. This latter movement has, to date, chiefly affected the well-to-do and the better paid class of artisans; but it is destined to persist until the homes and the environment surrounding the poorest are bettered. The cities are indeed growing very rapidly; but the foreshadowing of a new, more hopeful movement is there in their midst. Every demand for civic beauty and cleanliness is a demand for space and rapid transit.

A cursory glance at the worker employed in machine production reveals the fact that he has been reduced to the position of a mere machine tender. Long hours devoted to this kind of work makes a man narrow, it blunts his sensibilities; he finally becomes like unto the machine he tends. Machine production is a necessary accompaniment of our civilization; the machine is to remain among us, nor do we wish to dispense with its services. The machine must be used so as to benefit, not degrade mankind. The hope of the worker is in a shorter working day. If a shorter working day is obtained will the worker, is he able to, improve his leisure time? In other words, is a desirable and beneficial use of leisure time probable in the crowded portion of a city with its dull, monotonous scenery; its noise, hurry and smoke; its foul odors, bad streets and worse places of amusement or debauchery; its lack of natural scenery, fresh air and wholesome food? Amelioration of conditions is possible, feasible and desirable; but a movement of manufacture to the suburbs, the development of

rapid suburban transit, the revival of village industry in the skilled trades and education which tends to raise the standard of living, are the real panaceas for the evils of the crowded city. Our statesmen can aid in hastening the solution of the problem by directing their attention toward the regulation of steam and electric railroads.

Agriculture also is undergoing a transformation; it is changing, in this country, from extensive to intensive methods. Our greatest industry does not readily lend itself to consolidation and combination. The small and medium sized farm triumphs, in the long run, over the bonanza farm, except perhaps in the cultivation of such crops as cotton, sugar-cane and tobacco, where the plantation system seems destined to continue. As the population increases the big farm breaks up and disappears, leaving several smaller ones in its place. Farming must, therefore, be classed with those occupations which do not readily submit to minute division of labor, or extreme specialization of industry. Scientific agriculture must be classed among those industries or trades which require skilful and artistic individual work. Its possibilities are not generally realized. The era of free public land is practically over. Men can no longer go west and take up new, unbroken ground. A few decades ago the competition of the newly opened western lands injured temporarily the farming regions of the eastern and north central states. To-day the situation is changing, many western farms have been robbed of their virgin fertility by uneconomical and short-sighted farming, and the eastern farmer is daily finding new opportunities for profitable agriculture. Dairy farming, stock raising, horticulture and market gardening are more and more attracting his attention. Scientific methods are being adopted; renewal of soil fertility is the first care. The 'good' farmer is one who makes a profit at the end of the season, and who also preserves unimpaired the fertility of the soil. To be a successful farmer in this country it will be necessary to have definite ideas regarding farm management, and the proper methods of crop rotation and fertilization must be understood. Business methods must be adopted, and the cost of each crop must be accurately determined. The farmer will be obliged to keep in close touch with the industrial and commercial life of the nation. Agriculture will be a business, and business principles will be applied. The era of the unscientific, haphazard, go-as-you-please style of farming is rapidly becoming obsolete. The rise of the agricultural college and secondary school, and the potent influence of the United States Department of Agriculture, together with the general introduction of the trolley, the telephone and rural mail delivery, mark a new and promising epoch in the history of American agriculture. The agricultural transformation will diminish the drain of ambitious young men from the farm to the factory, the store and the bank.

The formation of a numerous and influential suburban type of people may, therefore, be anticipated for three reasons: the introduction of new methods of transmitting and distributing power; an increasing demand for goods of a varied, unstandardized character; and the development of scientific intensive agriculture. The development of such a social type may be hastened by appropriate legislative action. The city will gradually take on many desirable rural characteristics; and, on the other hand, the country will receive the benefits of many hitherto purely urban conveniences. The characteristic rural and urban types will present fewer dissimilar and discordant features. Decentralization—the merging of the urban and rural into the suburban—only can remove the well-known antagonism between the interests of city and country. State political machines have been constructed upon the foundations laid and cemented by this mutual antagonism and distrust between the city man and the farmer. True representative government breaks down and becomes a farce in the face of such an unfortunate situation. This line of demarcation may, as the suburb grows, be expected to fade away until the two types blend into the suburban; and then the forbidding menace to our democratic institutions caused by the distinct and often divergent interests of country and city will be, in a large measure, removed. Legislative power can not initiate or suppress such a social and industrial movement, but it can accelerate or retard such a tendency.

NEWSPAPER FOOTBALL

By Professor EDWIN G. DEXTER,
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THAT the game of football as played at our schools and colleges is in ill repute with the people as a class, no one who keeps at all abreast of the times can deny. Nor can it be denied that there are many good reasons for the feelings of general disapproval. The game, in common with other athletic pursuits, puts an undue premium upon certain human (or inhuman) characteristics which are altogether at variance with the highest ideals of the institutions which maintain it. It has too, in some instances, established relations that are to be regretted with professional interests and professional methods. It has, through its immense popularity and consequent tremendous gate receipts, given rise to financial problems that are not easy of solution, and it is, according to the newspaper, seemingly excessively dangerous to life and limb. In spite of the gravity of the other deplorable features of the game, we can hardly doubt the present wide-spread revulsion of popular feeling is due most largely to the last mentioned cause, for it is the one most prominently before the people. The others are treated in an academic way in occasional articles and editorials which are read by comparatively few people, but during the football season no reader of the daily papers can fail to be impressed with the great number of news items, each relating to some fatality or instance of serious injury on the gridiron. Hardly a Sunday issue of any of our principal city dailies has appeared during the past football season without including from three to a dozen or even more of such paragraphs till one was led to wonder whether any of our pig-skin warriors would survive the campaign. So much at variance were these reports with prevailing sentiment and conditions in a few football quarters with which I was personally familiar that I was led at the close of the last football season to endeavor to find out whether the report fitted the facts more exactly in others. This I did by writing personal letters to all those reported 'seriously injured' in a number of the leading daily newspapers of the country. Each letter specified the particular injury reported, as well as the date of the game and asked the following questions:

1. Were you in good training?
2. How much time did you lose from school work because of the injury?
3. Have you entirely recovered?
4. Is there any probability that the injury will prove permanent?

In all 135 letters were sent out: 78 to players upon college teams; 39 upon public school teams—mostly high school—and 13 to players upon athletic-clubs and other unclassified teams.

Before discussing the particular replies to the letters, I wish to say that I recognize fully that in appealing for information to football men I am going to interested witnesses for testimony. If these men had not been partizans of football they would not have played the game and consequently would not have been injured. Yet the questions are largely those of fact and not of mere opinion, and I doubt if we should in any important way impeach their testimony. I recognize, too, a possible basis for criticism in my making the loss of time from class work the criterion for judging the seriousness of the injury suffered. It is probably true that one might meet with serious or even ultimately fatal mishap on the football field without immediate incapacitation for classroom work. Yet such cases would be in all probability exceedingly rare, and the question of class-absence taken in connection with the next two questions would seem to be sufficiently conclusive. If one had lost no time from an injury which at the time of answering the query—some weeks later—was entirely recovered, it would seem as if the injury was of no great consequence. Certain it is that no interference with the main aim of college life, *i. e.* study, had been suffered. The only other sufficiently definite criterion for the measure of the injury would be that of enforced absence from football practise. This does not seem to me to be as fair a basis of judgment as the other, since it means to measure the perfection of physical condition not by an ordinary, but by an extraordinary, physical stress. It would also involve the problem of saving a man for a particular game rather than keeping him out purely and simply because of the injury, and would thus tend to introduce error.

Up to the time of writing this paper (January 20), 84 replies have been received, 60 of which are from college men, 22 from high-school players and 2 from others. Twenty-four letters, have been returned marked by the postmaster 'no such person in the directory.' An analysis of the 60 replies from college men shows the following somewhat interesting facts:

First, that 14 of the number assert the entire falsity of the report; in one or two instances the man had not even played the game in question; in the rest, any injury whatsoever is denied.

Second, the 46 other college men acknowledge the report as true in a general way. Of this number, however, 24 say that the injury was the merest trifle and that *no time whatsoever was lost* from classes.

Third, the time lost from college work on the part of the 22 college players who specify some loss as follows:

1 hour	1
1 day	2
2 days	4
3 days	1
1 week	5
1 to 2 weeks	2

The remaining seven report a longer time averaging about a month, though three say 'am staying out until Christmas.'

Fourth, of the 60 college players reporting, twelve stated that at the time of answering my letter they had not wholly recovered from the injury. When we consider that in some instances the reply was made within a week or two of the time of injury and in no instance more than two months after, this number does not seem excessive. With the exception of the persons noted under fifth, the answers seem to indicate the later stages of convalescence. Some of them read: 'muscles still weak,' 'leg still in plaster cast but will be out in a few days,' 'still a little lame,' 'three teeth not yet recovered, but dentist doing his best,' 'ankle a little stiff yet' and 'have not fully recovered but was able to play the Nebraska, Wisconsin and Chicago games' (this from a Michigan man).

Fifth, on the part of five players it could not be said with certainty that the injury would not prove permanent. Michigan, Columbia, Harvard, Chicago and Illinois each has one in this class. For these men the particular injury and the reply to the question as to permanence are as follows:

(1) Ligament of knee ruptured. 'Can't say definitely. Think not.'

(2) Spine wrenched. 'Physicians say I shall ultimately recover.'

(3) Blow on head. 'My orders from the doctors are: If you remain quiet and take good care of yourself you will entirely recover.'

(4) Partial detachment of retina. 'It is not unlikely that a part of this area will remain permanently detached from choroid.' (Signed by physician).

(5) Knee injured, floating cartilage. 'Very serious and, unless an operation could eliminate it, the danger of a very unreliable knee.'

This completes the record of the college men, except for the fact that all but five assert that they were in good training. This, however, means nothing in itself, since we have no means of knowing what proportion of the whole number of men playing football were unseasoned.

With the high school players, the facts seem to coincide more nearly with the printed reports. Of these, twenty-two in all, but two denied the report in toto, although eight others stated that no time was lost from classes. The rest on the whole lost a considerably larger average

of time than did the college men. A delightfully optimistic lot of boys were these gridiron youngsters, not one of whom would grant the slightest possibility of permanent injury. One acknowledged 'a fine headache for several days and a slightly crooked nose which was the fault of the *Docktor.*' Another adds: 'And I am glad to say I couldn't carry out the ashes.' Only eleven dared say that they were in good training.

In their bearing upon the purpose of this study, which was, as I have said, to determine if possible the accuracy of newspaper reports of football injury, what do these returns mean? Seemingly, so far as college players are concerned, they tend to prove the utter unreliability of the press reports. What are the facts in support of this? Seventy-eight reports of 'serious injury' to college men appear in a single season, many of them described in detail and under 'scare headlines.' From sixty of these persons replies were received, while the letters addressed to fourteen others are returned unopened, indicating in all likelihood that there was no such person, since in every instance the name, the team and the words 'football player' were on the envelope. And of the sixty heard from, but five can, it seems to me, with any degree of fairness be considered 'seriously injured,' and with them it is a question. Upon such reports is the present popular revulsion against football founded. Nor is the condition that I have pointed out either local or of recent standing. The reports that I have studied appeared in papers in all parts of the country, and a series of letters sent out by me at the close of the football season of 1902 gave results in no way differing from these. Of twenty-three college men reported seriously injured that season, 2 stated that the report was false; ten lost no time, and in every instance recovery was complete. If it were not for the tragedy of it all, some of the reports would be better fitted for the comic supplement than the news columns. Note the following that appeared in a leading paper at the close of the last season under heavy headlines, '*The Dead and How They Were Killed.*'

> LATIMORE, JOSEPH, at Mukwonago, Wis. September 13. He was rubber down for the Northwestern University team at the training camp at Mukwonago. He had been left at quarters while the team went for a row. The manner of his drowning is not known. The body was found the next day.

The entire list contained the names of 18 others, who are presumably dead and supposedly so from the direct effect of football. Within a comparatively recent time one of the foremost daily papers of the country appeared with the scare headlines 'Football Player Killed,' for no more valid reasons in one case than the killing of an ex-football player by the cars on a grade crossing, and the other the electrocution of a boy on a scrub team, who had climbed an electric-light pole to remove the ball, which had, by accident, lodged in the lamp. Such

mishaps should not be charged up to the game. No advocate of the game of football should fear the truth so far as the dangers of the game are concerned, yet every believer in it has a right to resent the unfair playing upon popular fears and emotions by a public press that is either culpably careless in the gathering of news, or worse.

Football is not a gentle game, and the boy who is entirely satisfied with tiddle-dy-winks, as well as his father, who in his day had been satisfied with similar games, may deem it over-strenuous. But no youth of bone and muscle who hears even the faintest 'Call of the Wild' echoing down from a thousand generations of fighting ancestors—and they must have been fighters or they would never have been ancestors—comes to his own without somewhere and somehow a chance at the physical try out with worthy adversaries. With the days of almost universal war superseded by days of as universal peace and the knight-errant and the tournament things of the past, if we emasculate football and attempt to eliminate entirely the danger element, we shall close the last safety valve to virile expression and may well expect an explosion. Newspaper football is excessively dangerous, but is, after all, football of the college gridiron? In a statistical study which I have made covering ten years of play (1892–1902) in sixty-four leading colleges and universities, where 22,766 men played upon 1,374 different teams, but three men were fatally injured, eight permanently injured and but three men in each hundred sufficiently injured to lose time from their class work. And Harvard was within the list studied, in spite of what might be inferred from reports for the past season. President Hadley was right when he said a few days ago that football was not only not an excessively dangerous game as played at our colleges, but the least dangerous of the more important sports. But he was not speaking of newspaper football.

SUBMARINE NAVIGATION[1]

By Sir WILLIAM H. WHITE

SUBMARINE navigation has engaged the attention of inventors and attracted general interest for a very long period. Its practical application to purposes of war was made about 130 years ago. The main object of that application was to threaten, or if possible destroy, an enemy's battleships engaged in blockade by means of under-water attacks, delivered by vessels of small dimensions and cost, which could dive and navigate when submerged. From the first, submarines were admittedly weapons favored by the weaker naval power; and as a consequence their construction found little favor with our naval authorities. Under the conditions which prevailed a century ago in regard to materials of construction, propelling apparatus and explosives, the construction of submarines necessarily proceeded on a limited scale, and the type practically died out of use, almost at its birth. Enough had been done, however, to demonstrate its practicability and to make it a favorite field of investigation for inventors, some of whom contemplated wide extensions of submarine navigation. Every naval war gave fresh incentive to these proposals, and led to the construction of experimental vessels. This was the case during the Crimean War, when the Admiralty had a submarine vessel secretly built and tried by a special committee, on which, amongst others, Mr. Scott-Russell and Sir Charles Fox served. Again, during the civil war in America, the Confederates constructed a submarine vessel, and used it against the blockading squadron off Charlestown. After several abortive attempts, and a considerable loss of life, they succeeded in destroying the Federal *Housatonic,* but their submarine with all its crew perished in the enterprise.

It is impossible to give even a summarized statement of other efforts made in this direction from 1860 onwards to 1880; but one cannot leave unnoticed the work done in the United States by Mr. Holland, who devoted himself for a quarter of a century to continuous experiment on submarines and eventually achieved success. The Holland type was first adopted by the United States Navy, and was subsequently accepted by the British Admiralty as the point of departure for our subsequent construction of submarines. In France also successive designs for submarines were prepared by competent naval architects, and a few vessels were built and tried. The *Plongeur,* of 1860, was a submarine of large size, considerable cost and well-considered design; but her limited radius of action and comparatively

[1] An address before the Royal Institution of Great Britain.

low speed left her for many years without a successor on the French navy list. The high relative standing attained by the French navy as compared with our own, in consequence of the vigorous action of the Emperor Napoleon III. in developing steam propulsion and armor protection for sea-going ships, no doubt greatly influenced French policy at that time, and delayed development of submarine construction. When conditions were altered in consequence of the Franco-German war of 1870, and the position of the French navy in relation to the British became less favorable, it was natural that the question of submarine construction should assume greater importance in France. In the interval, moreover, great advances had been made in materials of construction and in means of propulsion available for submarines. The extended use of steel and the practical applications of electricity gave to designers greater facilities than existed previously, and public interest in the construction of submarines and small swift vessels was increased by the writings of the *jeune école,* who strongly condemned the continued construction of armored 'mastodons.'

The modern development of submarines for war purposes is chiefly due to French initiative. During the earlier stages of this development progress was extremely slow. The *Gymnote* was ordered in 1886 and the *Gustave Zédé* in 1888, and her trials continued over nearly eight years, large sums of money being spent thereon. In 1896 competitive designs for submarines were invited, but no great activity was displayed in this department of construction until the Fashoda incident two years later. Since that time remarkable developments have been made in France, considerable numbers of submarines have been laid down, rival types have been constructed, and many designers have been engaged in the work. Up to the present time about seventy submarines and submersibles have been ordered; in July, 1904, the total number of completed vessels was twenty-eight; and at the end of 1907 it is estimated that France will possess sixty completed submarines, with a total displacement of nearly 13,600 tons. The first French submarine of modern type, the *Gymnote,* was 56 feet long, and of 30 tons displacement. The latest types are nearly 150 feet long and of 420 tons displacement. The cost of a French submarine designed in 1898 was about 26,000*l.* The estimated cost of the latest and largest vessel is about 70,000*l.* The French have pursued no continuous policy in this development, but have alternated between vessels of comparatively large, and others of much smaller displacement. This course had much to recommend it, no doubt, as it brought many accomplished naval architects into competition; but the lack of a continuous and progressive policy has resulted in dissatisfaction and difficulty, and this is frankly acknowledged by French authorities. Two years elapsed after the date when the French resolutely undertook the construction of submarines before the British Admiralty ordered five vessels of the Hol-

land type from Messrs. Vickers, Maxim and Co., who had acquired the concession for the use of the Holland Company's patents. These first vessels in essentials were repetitions of the type which had been tried and officially approved by the authorities of the United States Navy. It was agreed that all improvements made by the Holland Company should be at the service of the British Admiralty through the English *concessionaires*. In this manner the royal navy at once acquired advantages attaching to the long experience and great skill of Mr. Holland; and with that advantage there was associated the possibility of utilizing their own technical resources and those of Messrs. Vickers, Maxim and Co. For five years a continuous policy has been followed in the development of our submarines, all of which have been constructed at Barrow-in-Furness. There has been a great development in size, speed and general efficiency, resulting necessarily in correspondingly greater cost per vessel. Information of an official and authoritative character relating to submarines is freely published in France and the United States, but for British submarines, corresponding official information is scanty. It has for years been the rule to give in the navy estimates full particulars of dimensions and costs for all other classes of British warships; but for submarines a policy of secrecy is adopted that is most unreasonable and unnecessary. From the best sources of information accessible, it appears that the growth in size, with a correspondingly increased cost, has been even more rapid here than in France. Our first five submarines are 63 feet in length, 120 tons in displacement, with gasolene engines of 160 horse-power for surface propulsion, giving a speed of 8 to 9 knots. The electric motors for submerged propulsion are estimated to give a speed of about 7 knots. The contract price for each vessel in the United States was about 34,000*l.*, and that is about the price paid for our earliest vessels. The latest type of which particulars are available are said to be about 150 feet in length, 300 tons in displacement, and with gasolene engines of 850 horse-power for surface propulsion, giving a surface speed of 13 knots and a radius of action of 500 miles. The under-water speed is 9 knots, and the radius of action when submerged about 90 miles. No official particulars have been published as to the contract price for these vessels, which is certainly an undesirable course to adopt, seeing that for other and admittedly sufficient reasons these contracts have not been subject to competition as yet. It may be hoped that the admiralty will reconsider this matter and treat submarines similarly to other vessels.

In French official classification a distinction is made between submarines and submersibles, and this terminology has been the cause of some confusion. Both classes are capable of diving when required, and both can make passages at the surface. In this surface condition a considerable portion of the vessel lies above the water-surface and

constitutes what is technically called a 'reserve of buoyancy.' In the submersible this reserve of buoyancy and the accompanying freeboard is greater than in the submarine type, and in this respect lies the chief difference between the two types. The submersible has higher freeboard and greater reserve of buoyancy, which secure better seagoing qualities, and greater habitability. The deck or platform is situated higher above water, and to it the crew can find access in ordinary weather when making passages, and obtain exercise and fresh air. Recent exhaustive trials in France are reported to have established the great superiority of the submersible type when the service contemplated may involve sea passages of considerable length. The French policy, as recently announced, contemplates the construction of submersibles of about 400 tons displacement for such extended services, and proposes to restrict the use of submarines to coast and harbor defence for which vessels of about 100 tons displacement are to be employed. All recent British submarines would be ranked as submersibles according to the French classification, and it is satisfactory to know, as the result of French experiments, that our policy of construction proves to have distinct advantages. In addition to these two types of diving or submarine vessels, the French are once more discussing plans which have been repeatedly put forward and practically applied by M. Goubet, namely, the construction of small portable submarine vessels which could be lifted on board large ships and transported to any desired scene of operations. In the Royal Navy for many years past, it has been the practise to similarly lift and carry second-class torpedo or vedette boats about 20 tons in weight. Lifting appliances for dealing with these heavy boats have been designed and fitted in all our large cruisers and in battleships, and a few ships have been built as 'boatcarriers.' The first of these special depôt ships in the royal navy was the *Vulcan* ordered in 1887–8, the design being in essentials that prepared by the writer at Elswick in 1883. The French have also built a special vessel named the *Foudre* which has been adapted for transporting small submarines to Saigon, and performed the service without difficulty. Whether this development of small portable submarines will take effect or not remains at present an open question, but there will be no mechanical difficulty either in the production of the vessels themselves or in the means for lifting and carrying them. M. Goubet worked out with complete success designs for vessels about 26 feet long and less than 10 tons displacement, with speeds of 5 to 6 knots, the trials of which have been very fully described, but French authorities have not adopted the type, and no decision seems to have been taken to introduce it. In this country no similar action has been taken, and our smallest submarines weighing 120 tons cannot be regarded as 'portable.' Indeed, some leading British authorities on submarines have indicated that experience is adverse to the construction of vessels in which not

more than two or three men would form the crew, and on that ground have condemned the construction of these small submarines. They would necessarily be of slow speed and very limited radius of action, while their efficient working would depend upon the nerve and skill of only two or three men working in a very confined space.

Progress in mechanical engineering and in metallurgy has been great since Bushnell constructed and used his first submarine in 1776, during the war between the United States and this country. These advances have made it possible to increase the dimensions, speed and radius of action of submarines; their offensive powers have been enlarged by the use of locomotive torpedoes; and superior optical arrangements have been devised for discovering the position of an enemy while they themselves remain submerged. But it cannot be claimed that any new principle of design has been discovered or applied. From descriptions left on record by Bushnell and still extant, it is certain that he appreciated, and provided for the governing conditions of the design in regard to buoyancy, stability, and control of the depth reached by submarines. Indeed Bushnell showed the way to his successors in nearly all these particulars, and—although alternative methods of fulfilling essential conditions have been introduced and practically tested—in the end Bushnell's plans have in substance been found the best. The laws which govern the flotation of submarines are, of course, identical with those applying to other floating bodies. When they are at rest and in equilibrium they must *displace* a weight of water equal to their own total weight. At the surface they float at a minimum draught and possess in this 'awash' condition a sufficient freeboard and reserve of buoyancy to fit them for propulsion. When submarines are being prepared for 'diving' water is admitted to special tanks, and the additional weight increases immersion and correspondingly reduces reserve of buoyancy. In some small submarines comparative success has been attained in reaching and maintaining any desired depth below the surface simply by the admission of the amount of water required to secure a perfect balance between the weight of the vessel and all she contains, and the weight of water which would fill the cavity occupied by the submarine when submerged. For all practical purposes and within the depths reached by submarines on service water may be regarded as *incompressible;* the submarine should, therefore, rest in equilibrium at any depth if her total weight is exactly balanced by the weight of water displaced. If the weight of the vessel exceeds by ever so small an amount the weight of water displaced, that excess constitutes an accelerating force tending to sink the vessel deeper. On the contrary, if the weight of water displaced exceeds by ever so small an amount the total weight of the vessel, a vertical force is produced tending to restore her to the surface. Under these circumstances, it is obvious that if the admission or expulsion of water from internal tanks (or the

extrusion or withdrawal of cylindrical plungers for the purpose of varying the displacement) were the only means of controlling vertical movement, it would be exceedingly difficult to reach or to maintain any desired depth. This difficulty was anticipated on theoretical grounds, and has been verified on service—in some cases, with considerable risks to the experimentalists—the submarines having reached the bottom before the vertical motion could be checked. It has consequently become the rule for all submarines to be left with a small reserve of buoyancy when brought into the diving condition. Submergence is then effected by the action of horizontal rudders controlled by operators within the vessels. Under these conditions, submergence only continues as long as onward motion is maintained, since there is no effective pressure on the rudders when the vessel is at rest. The smallest reserve of buoyancy should always bring a submarine to the surface if her onward motion ceases, and, as a matter of fact, in the diving condition that reserve is extremely small, amounting to only 300 lbs. (equivalent to 30 gallons of water) in vessels of 120 tons total weight. This is, obviously, a narrow margin of safety, and necessitates careful and skilled management on the part of those in charge of submarines. A small change in the density of the water, such as occurs in an estuary or in the lower reaches of a great river, would speedily obliterate the reserve of buoyancy and cause the vessel to sink if water was not expelled from the tanks. Moreover, variations in weight of the submarine (due to the consumption of fuel, the discharge of torpedoes or other causes) must sensibly affect the reserve of buoyancy, and arrangements must be made to compensate for these variations by admitting equal weights of water in positions that will maintain the 'trim' of the vessel. Additional safeguards against foundering have been provided in some submarines by fitting detachable ballast. The more common plan is to make arrangements for rapidly expelling water from the tanks either by means of pumps or by the use of compressed air. In modern submarines, with locomotive torpedoes, compressed air is, of course, a necessity, and can be readily applied in the manner described if it is desired to increase their buoyancy.

The conditions of stability of submarines when diving, are also special. At the surface, owing to their singular form, the longitudinal stability is usually much less than that of ordinary ships. When submerged, their stability is the *same in all directions*, and it is essential that the center of gravity shall be kept below the center of buoyancy. This involves no difficulty, because water-ballast tanks can be readily built in the lower portions of the vessel. Small stability in the longitudinal sense, however, necessitates great care in the maintenance of trim, and in the avoidance of serious movements of weights within the vessels. Moreover, when a vessel is diving under the action of her longitudinal rudders, she is extremely sensitive to changes of trim, and

great skill is required on the part of operators in charge of working the rudders. As the under-water speed is increased, the pressure on the rudders for a given angle increases as the *square* of the velocity, and sensitiveness to change of trim becomes greater. This fact makes the adoption of higher under-water speed a matter requiring very serious consideration. Some authorities, who have given great attention to the construction of submarines, have been opposed to the adoption of high speeds under water, because of the danger that vessels when diving quickly may reach much greater depths than are desirable. Causes of disturbance which might be of small importance when the under-water speed is moderate, may have a greatly exaggerated effect when higher speeds are reached. Cases are on record where modern submarines in the hands of skilled crews have accidentally reached the bottom in great depths of water, and have had no easy task to regain the surface. For these reasons, it is probable that while speeds at the surface will be increased, under-water speeds will not grow correspondingly. Indeed, the tactics of submarines hardly appear to require high speed under water, seeing that it is an important element in successful attack to make the final dive at a moderate distance from the enemy. It is authoritatively stated that in our submarines complete control of vertical movements has been secured by means of skilled operators, and that a constant but moderate depth below the surface can be maintained. Proposals have been made and successfully applied to small submarines for automatically regulating the depth of submergence by apparatus similar to that used in locomotive torpedoes. For the larger submarines now used such automatic apparatus does not find favor, and better results are obtained with trained men.

The possibility of descending to considerable depths has to be kept in view when deciding on the form and structural arrangements of submarines, which may be subjected accidentally to very great external pressure. It is absolutely necessary to success that, under the highest pressure likely to be endured, there shall be rigidity of form, as local collapse of even a very limited amount might be accompanied by a diminution in displacement that would exceed the reserve of buoyancy. This condition is not difficult of fulfillment, and the approximately circular form usually adopted for the cross-sections of submarines favors their resistance to external pressure.

Under former conditions, there was difficulty in remaining long under water without serious inconvenience from the impurity of the air. Now, by suitable arrangements and chemical appliances, a supply of pure air can be obtained for considerable periods, sufficient indeed for any operations likely to be undertaken.

The use of gasolene engines for surface propulsion has many advantages. It favors increase in speed and radius of action, and enables submarines to be more independent and self-supporting. Storage

batteries can be recharged, air compressed and other auxiliary services performed independently of any 'mother' ship. At the same time, it is desirable to give to each group of submarines a supporting ship, serving as a base and store depôt, and this has been arranged in this country as well as in France. With gasolene engines, care must be taken to secure thorough ventilation and to avoid the formation of explosive mixtures of gas and air, otherwise accidents must follow.

Little information is available as regards the success of 'periscopes' and other optical instruments which have been devised for the purpose of enabling those in command of submarines to obtain information as to their surroundings when submerged. In this department secrecy is obviously desirable, and no one can complain of official reticence. From published accounts of experimental working abroad as well as in this country, it would appear that considerable success has been obtained with these optical instruments in comparatively smooth water. It is also asserted that when the lenses are subjected to thorough washing by wave-water, they remain efficient. On the other hand, the moderate height of the lenses above water must expose them to the danger of being wetted by spray even in a very moderate sea, and experience in torpedo-boats and destroyers places it beyond doubt that the resultant conditions must greatly interfere with efficient vision. In heavier seas, the comparatively small height of the lenses above water must often impose more serious limitations in the use of the periscopes and similar instruments. Improvements are certain to be made as the result of experience with these optical appliances, and we may be sure that in their use officers and men of the Royal Navy will be as expert as any of their rivals. But when all that is possible has been done, it must remain true that increase in offensive power and in immunity from attack obtained by submergence will be accompanied by unavoidable limitations as well as by special risks, resulting from the sacrifice of buoyancy and the great reduction in longitudinal stability which are unavoidable when diving. These considerations have led many persons to favor the construction of so-called *surface-boats* rather than submarines. They would resemble submersibles in many respects, but the power of diving would be surrendered, although they would be so constructed that by admitting water by special tanks they could be deeply immersed and show only a small target above the surface when making an attack. There would be no necessity in such surface vessels to use electric motors and storage batteries, since internal combustion engines could be used under all circumstances. Hence it would be possible without increase of size to construct vessels of greater speed and radius of action and to simplify designs in other important features. It is not possible to predict whether this suggestion to adopt surface-boats rather than submersibles will have a practical result; but it is un-

questionable that improvements in or alternatives to internal combustion engines will favor the increase of power in relation to weight, and so will tend to the production of vessels of higher speed. The comparatively slow speed of existing submarines as compared with destroyers and torpedo-boats of ordinary types admittedly involves serious limitations in their chances of successful attack on vessels under way, and higher surface speeds are desirable.

Concurrently with the construction of submarines, experiments have been made in this country and abroad to discover the best means of defence against this method of attack. Here again authentic details are necessarily wanting, since the various naval authorities naturally wish to keep discoveries to themselves. It is very probable, however, that published accounts of tests between swift destroyers, vedette boats and submarines are not altogether inaccurate, and according to these accounts the periscopes of submarines have been found useful by assailants as the means of determining the position of the submarines, and aiding their entanglement. Comparatively limited structural damage to a submarine in the diving condition may be accompanied by an inflow of water in a short period, which will result in the loss of the vessel. The accident to Submarine A 1, which was struck by a passing mail steamer, illustrates this danger. It is reasonable to accept the published reports that large charges of high explosives exploded at a moderate distance may have a serious effect against submarines, and cause them to founder. Their small reserve of buoyancy in the diving condition makes them specially liable to risks of foundering rapidly, and little more than a crevice may practically fill the interior with water in a very short time when the vessel is submerged even to a moderate depth. On the other hand, reports which have appeared of the manœuvres in France and elsewhere, when attacks have been made by submarines on vessels at anchor or under way, show a considerable percentage of successes. Such exercises are valuable no doubt for purposes of training, but under peace conditions it is necessary to avoid the risks of damage to submarines, which might easily become serious if the defence were pressed home as it would be in war. When the officers and crews of submarines know that they will be treated more considerately than in real warfare, they will naturally take chances, and make attacks involving possible destruction under the conditions of a real action. In short, naval manœuvres in this department, while they may be useful in increasing the skill and confidence of officers and men in the management of submarines, can be no real test of fighting efficiency.

Submarines and airships have certain points of resemblance, and proposals have been made repeatedly to associate the two types, or to use airships as a means of protection from submarine attacks. One French inventor seriously suggested that a captive balloon attached to

a submarine should be the post of observation from which information should be telephoned to the submarine as to the position of an enemy. He evidently had little trust in periscopes, and overlooked the dangers to which the observers in the car of the balloon would be exposed from an enemy's gun-fire. Quite recently a proposal has been made by M. Santos Dumont to use airships as a defence against submarines; his idea being that a dirigible airship of large dimensions and moving at a considerable height above the surface of the sea, could discover the whereabouts of a submarine, even at some depth below the surface, and could effect its destruction by dropping high explosive charges upon the helpless vessel. Here again, the inventor, in his eagerness to do mischief, has not appreciated adequately the risks which the airship would run if employed in the manner proposed, as submarines are not likely to be used without supporting vessels. Hitherto, submarines themselves have been armed only with torpedoes, but it has been proposed recently to add guns, and this can be done, if desired, in vessels possessing relatively large freeboard. No doubt if gun armaments are introduced, the tendency will be to further increase dimensions and cost, and the decision will be governed by the consideration of the gain in fighting power as compared with increased cost.

Apart from the use of submarine vessels for purposes of war, their adoption as a means of navigation has found favor in many quarters. Jules Verne in his 'Twenty Thousand Leagues under the Sea,' has drawn an attractive picture of what may be possible in this direction, and others have favored the idea of combining the supposed advantages of obtaining buoyancy from bodies floating at some depth below the surface with an airy promenade carried high above water. Not many years ago an eminent naval architect drew a picture of what might be accomplished by utilizing what he described as the 'untroubled water below' in association with the freedom and pure air obtainable on a platform carried high above the waves. These suggestions, however, are not in accord with the accepted theory of wave motion, since they take no note of the great depths to which the disturbance due to wave-motion penetrates the ocean. The problems of stability, incidental to such plans, are also of a character not easily dealt with, and consequently there is but a remote prospect of the use of these singular combinations of submarine and aerial superstructures. There is little likelihood of the displacement of ocean steamships at an early date by either navigable airships or submarines, and the dreams of Jules Verne or Santos Dumont will not be realized until much further advance has been made in the design and construction of the vessels they contemplate.

TRIAL AND ERROR AS A FACTOR IN EVOLUTION

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SINCE Darwin wrote there have been many general formulæ advanced under which all forms of development might be brought, and while each has sufficed for a time, each has been seen to fail and each has been replaced with greater or less completeness when tested by a new set of facts. While no one of the formulæ can be regarded as final, each has been valuable in so far as it has summarized the facts and points of view of the age under which it has developed.

Within the last decade there seem to be facts developing in varying fields that support a new formula, which, while perhaps not so definite in its explanation as many that have preceded it, can at least lay claim to very wide application. This generally stated is that all progress is the result of chance trials and a selection from the trials of those that are successful in attaining some end. The first formulation of the process in so many words seems to have been to describe the method by which animals learn. As Professor Thorndike and many later investigators have shown, an animal learns simply as the result of a selection from his chance movements—those which serve for some definite end. When a horse learns to open a gate or a dog to bring a stick through a fence, learning is accomplished by trying all possibilities until the end desirable at the moment is attained, and after it is once attained there is usually a smaller number of false movements and a shorter time of accomplishment at each succeeding trial, until finally all movements but the right one have been eliminated. These observations make a sufficient number of possible movements and a selecting agent the only essentials in the learning process.

From this comparatively modest starting point the doctrine has extended in both directions. It seems fairly evident from experiments that man must learn new movements in exactly the same way as the animal. He, too, can not be helped to learn by being put through the movement from outside. Knowledge of anatomical relations and rational external knowledge is valueless except as it serves as a point of departure. The only method by which the child or man can acquire new movements is by painfully trying and selecting the movements that most nearly accomplish the end in view.

Recently Professors Jennings and Holmes, in studies of the reactions of relatively low forms of life, seem to show that much that has

hitherto been regarded as an almost machine-like response to external stimulation is not made with the definiteness that has been supposed. On the contrary, what seems to take place is a feeling about for a favorable condition. When this is found there is either continued motion in this most favored direction or quiescence in the most favorable position. Here again we should have to do with trial and error, but with less complicated possibility of movement and, in all probability, with a different basis for the selection of the favorable condition.

Still a fourth expansion of the category of trial and error is possible in a metaphorical sense. This is to explain the general course of evolution. If we accept in all strictness the conclusions of Weismann, there is no possibility of foreseeing with very great accuracy any change in a race. Changes of one kind appear here, changes of another kind appear there. Aside from the conditions of mating, however, there is no way of tracing to any known causes the changes observed. We are left then with what, at the present stage of knowledge, seem entirely unforeseen and undetermined chance changes in the animal structure, with an accompanying set of instincts and general activities. The real determining factor is, of course, natural selection. In brief the environment determines which of the many forms and functions that originate by chance shall survive. By personification, and even more literally, we can think of the chance variations as the analogue of the trials of the individual animal, and survival as corresponding to the movement that is successful and so retained.

If we should then be permitted to generalize, we should have chance at the basis of all learning, all advancement, all adaptation. The primary facts would be the variation in structure, which would form the basis for all other adaptation. Within the organism at the lowest stage would be found adaptation from moment to moment on the basis of successful chance adjustment. At this stage, however, there is no learning. One adjustment is of no value for later activities, as the animal is at the same level, in the same condition, after the adaptive movement has been made as it was before. At the next stage, in addition to the increased complexity of the organism which makes possible more numerous movements, there is retention of the successful trials. A movement once made is accompanied by a change in the organism which makes that movement more likely to occur in the future. From this point upward there is variation in degree of complexity of possible movements, in the readiness with which movements once attained are retained and repeated, but there is no great change in the mechanics of the problem.

What does change throughout, and what is, after all, on this theory the essential factor in all development, is the selecting agent and the rewards which serve to make one thing permanent rather than another.

The selecting agent in the race is the environment, and the agent of selection is always life and death. If the organism varies in a way that is suitable, it lives and its progeny multiply. If, on the contrary, some variation be unfavorable, death is its punishment, the animal is eliminated, and nothing further is heard of it in the struggle for existence.

In the earliest forms, in the paramecium, upon which Professor Jennings has worked, or in the blow-fly larva, that Professor Holmes investigated, we can hardly imagine that there is much more than vague chemical activity or quiescence. When the light is favorable, motion directly ahead is preferred, or no motion at all. The animal moves away rather than towards the light when negatively phototactic merely because there is no physico-chemical tendency to draw back the head when it is turned away from the light and there is a stimulus which leads to general locomotion. We have to do with the rudiments of pleasure and pain, perhaps, but we can be sure of nothing more than increased tendency toward motion in one position and decreased tendency to movement in the other. It is approximately a mechanical equivalent of pleasure and pain.

At the next level of complexity in animal learning, the case is not so different. The simplest answer to the question is that the creature is controlled by pleasure and pain. It is not as clear as might be imagined at first sight what this means in last analysis, for, at the very lowest, pain and pleasure must go for their ultimate explanation to the evolution of the species. Other factors are perhaps to be found in the earlier experience of the animal and in even more remote circumstances. While we can not unravel the tangle of factors involved in what we call pleasure and pain, yet it may be interesting to indicate that, regarded as a selecting agent, neither is a simple thing but the result of many factors. It is at least worth while to indicate that the deciding factors here are conscious, as opposed to the chemical or physical processes in the organism or to the natural forces in the environment. There may be nothing really new or peculiar in the circumstances or conditions, but it does mean that we classify the manifestations under a new head. This alone makes it worth while to set the selecting agent off as belonging to a special class or group.

If we bring the different groups under a single general statement, we should have racial progress, due to the chance variations in the animal structures, and have as the selecting agent the environment, which enforces its decrees through the life or death of the organism, or, at least through its flourishing or its failure to flourish. The adaptation of the individual would take place in the lower forms through chance responses to stimulation, which were in the main not determined by the nature of the stimulus, but which attained their end by

a selection in terms of the chemical constitution of the organism. Each adaptation here is without influence upon later reactions, but each must be hit upon anew each time the circumstances arise. There is no learning. At the next stage again the response is brought about by chance, and the selection determines the process in its completeness, but there is here, on the one hand, a conscious pleasure and pain, and what is more certain and more important as an objective criterion, there is a permanent effect left upon the organism by the action once performed.

In man and perhaps in some of the higher animals the same general processes hold, but in addition to immediate organic processes of pleasure and pain there are new elements added to the selecting agencies, which may ultimately become pleasure and pain, but are only remotely organic in their origin. These in some way all seem to originate in the social *milieu*, all seem to have their origin in the phenomena connected with the living of man in groups. There are many things which seem indifferent to racial survival or to immediate pleasure and pain that will always and at once be repressed in terms of good manners or good form. Some traditional virtues strike one who has been reared in a given society as just as fundamental as others which can be shown to possess survival values, but we find civilizations of high rank which survive just as well without them. So, if an Anglo-Saxon were to select the fundamental virtues, modesty would be one of them. But let him consider for a moment the customs of the Japanese, and their national success, and then modesty would not seem so fundamental as it did at first sight.

These more subtle selecting agents act in the same way as the cruder. When any individual by chance departs from the traditional line of conduct, he is at times made to feel by popular attitude that he himself or his conduct is not welcome. It is not merely departure from the social norm that is repressed, but departure in certain ways that can not be foretold in advance of trial. Some innovations are welcomed and accepted and the discoverer made a social hero, exceptional man or genius. Others are checked in one or more of the insidious ways that in society are more effective than the arm of law. What determines this social selection, however, is not evident. In extremes it may be racial survival, in minor cases it may be what passes for esthetic appreciation, although esthetic appreciation can probably be reduced to social selection as well as social selection to esthetic appreciation.

One thing seems fairly evident, and this is that imitation does not play the important part in social selection or in any form of learning that has been supposed. In these higher forms, what we want explained is not the persistence of the traditional conduct, but the de-

termining factors in selecting some and eliminating other departures from the traditional methods of action. Even in the learning of children or of animals, the striking feature of the process is not the fact that the child gradually approaches the standard of society, but the method by which the approach is brought about. If you study a child learning to speak, it will at once be seen that there is no inherent impulse to repeat the sounds that are spoken, but that all sorts of movements are made, and those which in themselves are interesting or acquire vicarious interest from their resemblance to the sounds about are repeated until learned. The child does not imitate everything, although from the indifference of his interests he sometimes seems to. His imitation is not from a desire to reach an end; rather the child selects from the spontaneous unforeseen movements of all kinds those which strike his fancy. In spite of the fact, then, that there seems to be no instinct in the German child to speak German rather than English, he nevertheless selects from his varying movements those which resemble the sounds that he hears and so he learns to speak German. The sounds heard about him are by no means the incentive to the endeavor. Experiments seem to indicate that even in adults a knowledge of what it expected, or even a desire to execute a certain movement when one has exact anatomical knowledge of the parts to be moved, is no aid to its accomplishment in advance of trial. Much less then can we assume that the unappreciated presence of a sound can spur to its production by the child. The instincts that may serve to produce the sounds from which selection is made are varied and are the expression of numerous connecting paths in the nervous system. There is no evidence of an instinct or impulse to imitate for the sake of imitation.

The explanation of the numerous actions that are imitated by the child is to be found, on the one hand, in the great variety of useless movements at his command, and on the other in the wide range of his interests as yet unrestricted by the training that tends to restrain the adult individual in one relatively narrow line.

Imitation, then, seems to be a subordinate form of the general law of learning rather than learning a subordinate form of imitation. The explanation of learning that depends upon trial and error alone differs from an explanation in terms of imitation merely in that it makes individual appreciation of the results of a movement the essential element rather than the presence of a similar movement in some of the individual's neighbors. The two theories are alike in that the former must insist that seeing a fellow perform the movement is an important factor in raising individual appreciation. But they must differ in that it as firmly denies that seeing a movement performed is any incentive to its performance by the second individual. A move-

ment seen may become interesting if the organism chances to throw out a similar movement immediately after the first has been observed, but it will serve merely to make the individual repeat it a second time when once it has been made by chance; it will not serve to initiate a movement of itself.

The social factors which have been brought under the general term imitation have much the same relation to the more complicated conduct of the affairs of life that the simple copy has in spurring to the more simple and immediate action. They do not primarily initiate but serve to select factors otherwise initiated. Good form may lead to conscious imitation in an adult who already has command over the movement. Fashion may directly bring about imitation in the matters of dress, where the movements are already under control and mental processes alone are involved in the choice, but the impelling forces in society are those that make a man shunned who offends, and give him renewed applause when he initiates valuable lines of action. The enforcement of the moral law, apart from the material agencies, depends not upon precept or good example, but upon these vague social forces that are constantly repressing some and rewarding other departures from the accepted standards. Some of those rejected are rationally and by association apparently no worse than those retained. But social selection is none the less definite and absolute in fact because it seems irrational when attempt is made to explain it theoretically. The man who departs from the traditional course takes his reputation in his hands, for society is essentially conservative. Chances are that the result will be social death, and reasonably so, because the long course of evolution would probably make the existing the best, when we are dealing with any course of conduct that can have any survival value. Were it possible to reduce all the influences of social control to immediate or traditional survival values, the problem would be very much simpler than is really the case. Many courses of action which society represses most rigidly are apparently indifferent to survival, and many can not easily be shown to be associated with lines of action that could have been of value at present or at any earlier period.

The nature of the action selected will vary from civilization to civilization and from people to people and even from community to community within the same civilization. It does not seem possible as yet to push very far in the analysis of these elements, but it is nevertheless valuable to recognize their importance for both individual and sociological psychology. An insistence upon the importance of this factor under the term imitation or what else has probably been the most important contribution that psychological sociology has made, and an analysis into its elements and tracing it back to causes would undoubtedly have even more important results.

Looking back upon our general summary of this modern formulation of development as a whole we may ask what its value may be. The chief importance lies in the fact that it permits one to bring the generally accepted facts of racial and individual development under a single phrase. Even though the words are used in a slightly different sense, it is evident that chance gives the variations upon which all development must be based, even though the factors that we must assume to bring about the chance result are not altogether the same in the racial as in the individual development. The process of selection is also much the same throughout, for selection results from mere survival of one and rejection of others.

The main lack in the formula is our inability at present to analyze or define all the selecting agents. The environment in general which serves as the agent in racial development is comparatively well understood, or at least the meaning of the word and the methods of producing results give definite pictures. On the other hand, the physico-chemical constitution of the organism which must be assumed in the lowest organisms, and the intimate nature of social pressure which is effective in man both need much more complete analysis. And even pleasure and pain are not as simple or as free from ambiguity as we are inclined to suppose at first sight. But at least each of them marks a fairly definite field for investigation and will serve in so far to satisfy the needs of a formulation of the facts already known, and act as a spur to further work.

THE PROGRESS OF SCIENCE

THE REWARDS OF SCIENTIFIC RESEARCH

Our economic system rests on the free exchange of services. A state of society may some day be reached in which each will aim to give as much as he can and to take as little, but at present it appeals to our sense of fairness that each should ask for his services what someone else is willing to pay. In the increasing complexity of our society this method is working two serious injustices. One of these is the formation of monopolies. Thanks chiefly to the applications of science, many services can now be supplied at a cost less than people would be willing to pay. When free competition is excluded, either by the conditions of the case or by ingenious combination, people may be made to pay more than a fair return for certain services. The problems of monopoly are being discussed on all sides and remedies are being sought in all directions; but the injustice, which in a way is the converse of monopoly, has scarcely been noticed. This is the case in which an individual gives services without an adequate return, owing to the fact that they are not rendered to a single individual or group who will pay for them, but to society as a whole. A surgeon may ask for an operation for appendicitis as large a fee as his patient is willing to pay, but should he after years of research discover a method of preventing appendicitis altogether, he would receive no payment at all, but would, on the contrary, give up all future fees for the operation. The surgeons who by risking and sacrificing their lives discovered how to suppress yellow fever have received no return for their great services.

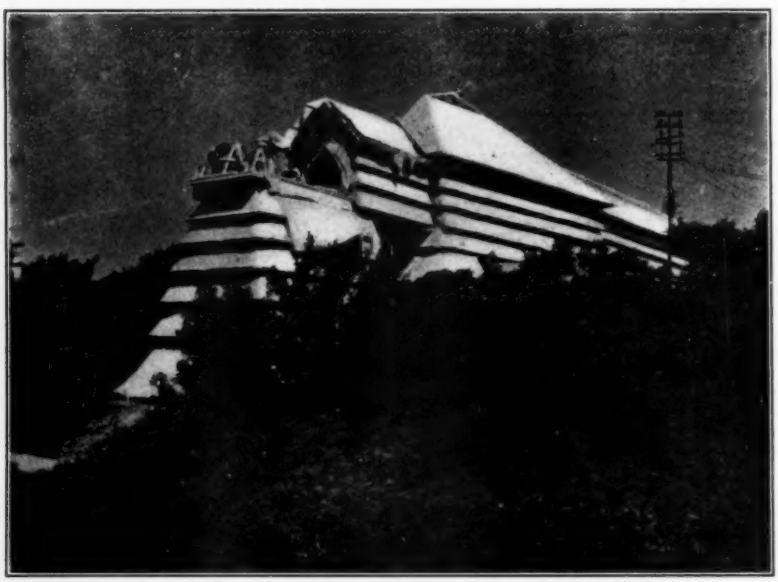
This state of affairs not only does injustice to the unrewarded individual, but works immeasurable harm to society—a greater injury probably than all existing monopolies. There are more than a hundred thousand physicians in the United States who are practising on their patients for fees, while there are scarcely five hundred who are studying seriously the causes of disease and the methods of preventing it. The conditions are similar in law and in all professions and trades. The scientific investigator is usually an amateur. He has wealth or earns his living by some profession, and incidentally does what he can to advance science for love of the work. This has its good side in producing a small group of men who are not subject to purely commercial standards. But this is after all a minor factor, and the scientific man is likely to look for fame, which is scarcely more ideal than money and can be supplied to but few. Satisfaction in the work itself is the best reward for work; but no one can know that his work is of value except by the reflected appreciation of others, and in the existing social order the simplest and probably the most adequate expression of this appreciation is direct payment for the service rendered.

The methods that society has devised to meet this situation, apart from the conferring of honors and fame, are recent and inadequate. Copyrights and patents are the most direct acknowledgment of property in ideas. They have accomplished a good deal, and their scope should be extended. At present only a small part of discovery is covered by the patent office, and this perhaps not the part requiring the greatest genius. It is, however, leading, especially in Germany, to the development of discovery

on a sound commercial basis. It is said that one chemical firm employs three hundred doctors of philosophy to carry on scientific investigations. Research has hitherto been forwarded mainly by the universities, where again Germany has led the way. The professorship is given as a reward for successful investigations, and the holder of a chair is expected to devote himself to investigation as well as to teaching. There is a tendency to permit certain professors to engage almost exclusively in research. Thus the astronomical observatories of Harvard, Chicago and California universities are purely research institutions. A further step has been taken in the endowment of institutions, such as the Carnegie Institution and the Rockefeller Institute, explicitly for research. The most logical and important advance, however, consists in the direct conduct of research by the government. As the government should control monopolies, so it should conduct the work which is not for the benefit of a single individual, but for the people as a whole. There are of course no end of difficulties in the control of monopolies or the conduct of research by a municipality, state or nation; but it is exactly these difficulties that it is our business to overcome. And we may congratulate ourselves that our national government is at present accomplishing more for research and the applications of science than the government of any other nation.

THE WORK OF THE CARNEGIE INSTITUTION

THE most important private foundation for the promotion of research is the Carnegie Institution of Washington, established four years ago by Mr. Andrew Carnegie with an endowment yielding an annual income of $500,000. The fourth year book, which has been recently issued, is of special interest as it is the first under the presidency of Dr. R. S. Woodward. The work of the year indeed was mainly fixed before the president entered on his office, but in his report to the trustees he gives some indications of the policy that he will recommend. He favors large projects carried on under the auspices



SOUTH END OF SNOW TELESCOPE HOUSE, SOLAR OBSERVATORY, MOUNT WILSON.

GROUNDS AND BUILDINGS OF THE STATION FOR EXPERIMENTAL EVOLUTION AT COLD SPRING HARBOR.

of the institution rather than smaller grants made to individuals in other institutions. Astronomy, geophysics and terrestrial magnetism have been especially favored in the past, and this policy will apparently be continued, as the two specific recommendations made by the president are an astronomical observatory in the southern hemisphere and a laboratory for geophysical research. He says that it seems best "to follow lines of least resistance, promoting chiefly those departments of research which promise sure returns, while seeking at all times to raise the less highly developed to the level of the more highly developed sciences."

LABORATORY BUILDINGS AT TORTUGAS, FROM THE NORTH, SHOWING THE DOCK AND AQUARIUM.

This is a safe policy. The original deed of gift and the act of incorporation leave more to the imagination, and many men of science had dreams of an institution that would become the chief center of scientific organization and inspiration for the country. But it is not fair to expect the impossible, and we should perhaps be satisfied if the institution conducts a geophysical laboratory as efficiently as it would be conducted under the Geological Survey and an astronomical observatory on Mt. Wilson doing as good work as that on Mt. Hamilton.

The large projects received, last year, grants as follows:

Station for Experimental Evolution	$ 12,000
Tortugas Marine Biological Laboratory	15,700
Desert Botanical Laboratory	6,000
Horticulture	10,000
Economics and sociology	30,000
Terrestrial magnetism	25,000
Historical research	14,000
Solar observatory	150,000
Geophysical research	24,000
Nutrition	16,000
Paleontology (transferred to minor grants)	1,800
Total	$304,500

The minor grants amounted to $130,625, including $26,000 to Professor R. Pumpelly for work in archeology and $10,000 for the conduct of the 'Index Medicus.' The following general appropriations have been made for the current year:

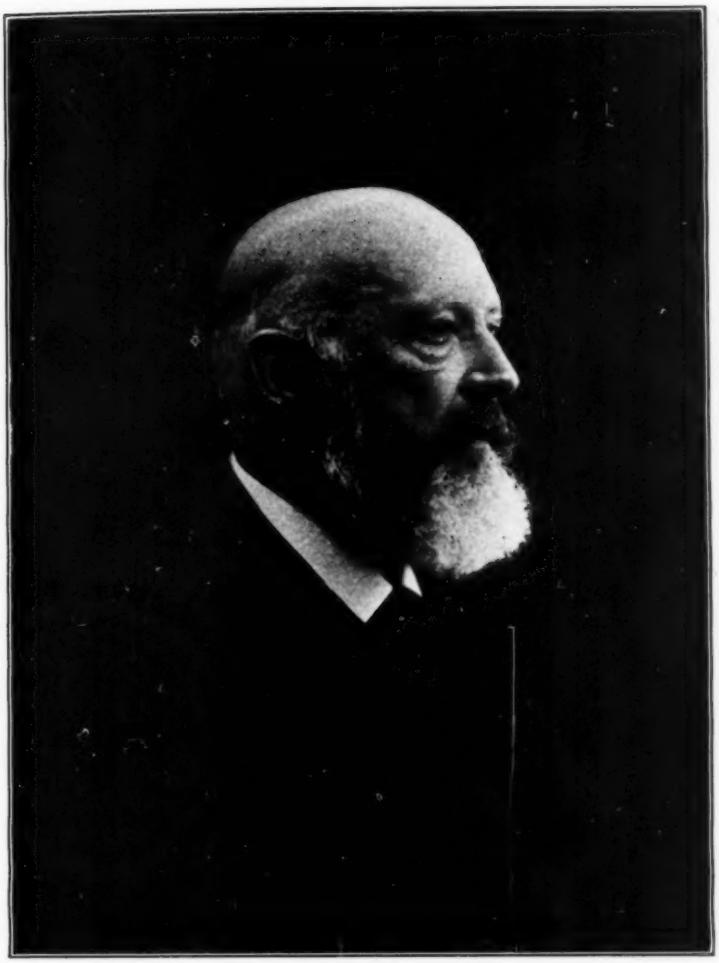
Publication fund to be continuously available	$ 50,000
Administration	50,000
Grants for departments and large projects	552,600
Grants for miscellaneous researches, including grants previously implied	134,000
Total	$786,600

No official announcement has been made of the new work that will be undertaken by the institution, but it may be assumed from the recommendations in the report of the president that the larger part of the appropriation for departments will go to the solar observatory on Mt. Wilson, an astronomical observatory in the southern hemisphere and a geophysical laboratory in Washington. It appears further that a department of botanical research has been established and placed under the direction of Dr. D. T. MacDougal.

An establishment such as the Carnegie Institution is face to face with many new and difficult problems. We regret that means have not been found to make the organization more truly democratic and representative of the scientific men of the country; we regret that its great resources have not been more directly applied to what it only could do. But whatever criticism may be directed against the institution, men of science will agree that the conduct of its work could not be in abler and safer hands than President Woodward's.

PROFESSOR ADOLF VON BAEYER

WE noted here recently the award of the Nobel prize in chemistry to Professor von Baeyer. The students and friends of the great German chemist have now published his collected works in celebration of his seventieth birthday, and thanks to the charming autobiographical sketch that is prefaced to the volumes we are able to give some facts in regard to his life and work, together with a portrait. Baeyer was born in Berlin, October 31, 1835, a member of the scientific and literary aristocracy of Germany. His father was an eminent geodesist, his mother's father, J. E. Hitzig, and his uncle, Franz Kugler, were at the center of the literary life of the city, and he had every advantage in the way of association and education. He began systematic chemical experiments at the age of nine and made a discovery of some importance at the age of twelve. While a school boy he made botanical excursions with Paul Ascherson, now professor of botany at Berlin, and extended explorations with Ferdinand von Richthofen, afterwards famous as a geographer. After three semesters at Berlin, Baeyer went to Heidelberg, where Bunsen's laboratory was the chief center of chemical research in Germany. Here he gained much from



PROFESSOR ADOLF VON BAEYER.

a large group of men active in research, especially from Kekulé, and began the investigations in organic chemistry which have made him eminent. It seems desirable to call attention to the great advantages that Baeyer had, which are paralleled in the lives of many other eminent men, because we need at the present time to learn how far scientific achievement is due to inborn genius and how far to favorable circumstances. It is quite possible that the dearth of distinguished men in the United States is less due to lack of natural ability than to the fact that fifty years ago the environment here was but rarely so favorable as in Germany, France or Great Britain.

Baeyer's fortunate career has continued to the present time. He followed Kekulé to Geneva but soon qualified as a docent in Berlin with a research on uric acid. His promotion at Berlin was slow, but he developed an important laboratory in connection with the Gewerbeakademie, where he had as students and assistants Liebermann, Graebe and Victor Meyer, and continued his work on the synthesis of

organic compounds. He was called to the chair of chemistry in the newly-organized university of Strassburg in 1872, where he had as students Emil and Otto Fischer, and three years later went to Munich as Liebig's successor. Liebig, who established the first chemical laboratory, had gone to Munich on the condition that he should do no laboratory teaching, and it remained for Baeyer to build up a university laboratory. Here he with his pupils and assistants has since continued to carry forward important researches in organic chemistry. His most important work, however, was the artificial production of indigo, accomplished in 1870, and made commercially possible in 1880. This has given Germany a new and important industry. It is a fine example of the interdependence of pure and applied science.

SCIENTIFIC ITEMS

THE German emperor has conferred on Professor Simon Newcomb, the eminent astronomer, the order 'pour le mérite' in science and the arts.—At a meeting of the Royal Astronomical Society, on February 9, Ambassador Reid received the gold medal for 1905, conferred by the society on Professor William Wallace Campbell, director of the Lick Observatory.

IT is planned to present to the city of Philadelphia a statue of Dr. Joseph Leidy, to be erected in the City Hall Plaza. Dr. Leidy, who was born in that city in 1823 and died there in 1891, added much to its scientific eminence, and as president of the Academy of Natural Sciences, professor of human and comparative anatomy and zoology in the University of Pennsylvania, and president of the Wagner Free Institute of Science, accomplished much for these institutions.

THE U. S. government has commissioned President David Starr Jordan, of Stanford University, and Professor Charles H. Gilbert, head of the department of zoology, to conduct an investigation of the fish and fisheries of Japan and the Island of Sakhalin during the coming summer.—Dr. Otto Nordenskjöld and Capt. Mikkelsen were the guests of honor at a dinner given by the Arctic and Explorer's Clubs in New York City, on February 7. It was announced that Dr. Nordenskjöld would sail on the 8th inst. for his home in Sweden, to arrange for another voyage in search of the south pole. Capt. Mikkelsen is getting ready an expedition to the Beaufort Sea, an unexplored Arctic area west of the Parry archipelago.